NIES Annual Report
2012
AE - 18 - 2012

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http://www.nies.go.jp/

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Foreword

This annual report is the official record of activities at the National Institute for Environmental Studies (NIES) in Fiscal Year (FY) 2011 (April 2011 to March 2012). FY2011 marked the beginning of the third NIES five-year plan (2011-2015). The Great East Japan Earthquake occurred in the final month of the previous Fiscal Year, on March 11, 2011. Despite the facilities of the institute sustaining damage in the earthquake, NIES immediately implemented initiatives towards recovery and restoration in the disaster zone in the direct aftermath of the disaster, and is contributing greatly in every field through these efforts. In the NIES Annual Report FY2011, we reported on the outcomes of the institute's activities in the run up to March 10, 2011, and in the current annual report we also incorporate the activities undertaken in the wake of the disaster.

The research strategy under the third five-year plan is made up of four parts. The first such part is the advancement of the eight pillar fields of environmental research undertaken at the Center for Global Environmental Research, the Center for Material Cycles and Waste Management Research, the Center for Environmental Risk Research, the Center for Regional Environmental Research, the Center for Environmental Biology and Ecosystem Studies, the Center for Environmental Health Sciences, the Center for Social and Environmental Systems Research, and the Center for Environmental Measurement and Analysis. At these eight centers, we are striving towards the achievement of our goals, developing environmental research while continuing to pursue integrated interdisciplinary ties in the full spectrum from fundamental to issue-driven research.

The second part of our strategy involves the ten issue-driven research programs. Building on research outcomes under the second five-year plan (2006-2010), these are research topics requiring a prompt and focused response, or those which should be tackled while making the most efficient use of the limited resources available. The third part involves the maintenance of medium- to long-term initiatives in step with the sustainment and advancement of environmental research. This includes the maintenance of equipment and facilities needed for initiatives such as the observation and analysis of the environment by means of global environmental monitoring, including that of greenhouse gases by satellite; the storage and provision of environmental reference materials; the maintenance of reference laboratory functions; and the creation of databases for various types of data relating to the environment. NIES also acts as the core center for the Japan Environment and Children's Study (JECS), the implementation of which is gathering momentum in the current period. In this capacity we are responsible for the integrated management and operation of the study, on the basis of this fundamental strategy of the Ministry of the Environment.
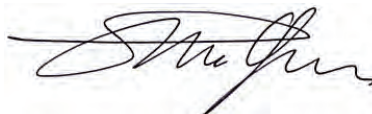
The fourth part of our strategy involves contributions, via research into radioactive materials and disasters and the environment etc. - including field studies and site surveys - towards recovery and restoration from the Great East Japan Earthquake. This makes use of the accumulated knowledge and expertise available at NIES as well as the other knowledge networks to which the institute has access.

In all of the above components of the research strategy, we have been able to produce tangible results while benefitting from the collaboration of many external researchers and other concerned parties. In

addition, the efforts of our different research centers and administrative departments, including the environmental information department, the planning department and the general affairs department, to promote mutual ties, have facilitated the implementation of research initiatives in a manner both efficient and effective.

The environmental topics being handled at NIES greatly influence all kinds of policy issues, such as those pertaining to national security, economic growth and research and development. To these we have added the perspectives and developments associated with research on the environment which takes into account the impacts of the Great East Japan Earthquake. By maintaining a close dialogue with the nation's citizens and the rest of the world, we are continuing to implement committed research on the environment. We hope that the NIES Annual Report 2011 goes some way to giving you a deeper understanding of the initiatives of our institute and we welcome a full and frank expression of your opinions on these activities.

OHGAKI, Shinichiro.
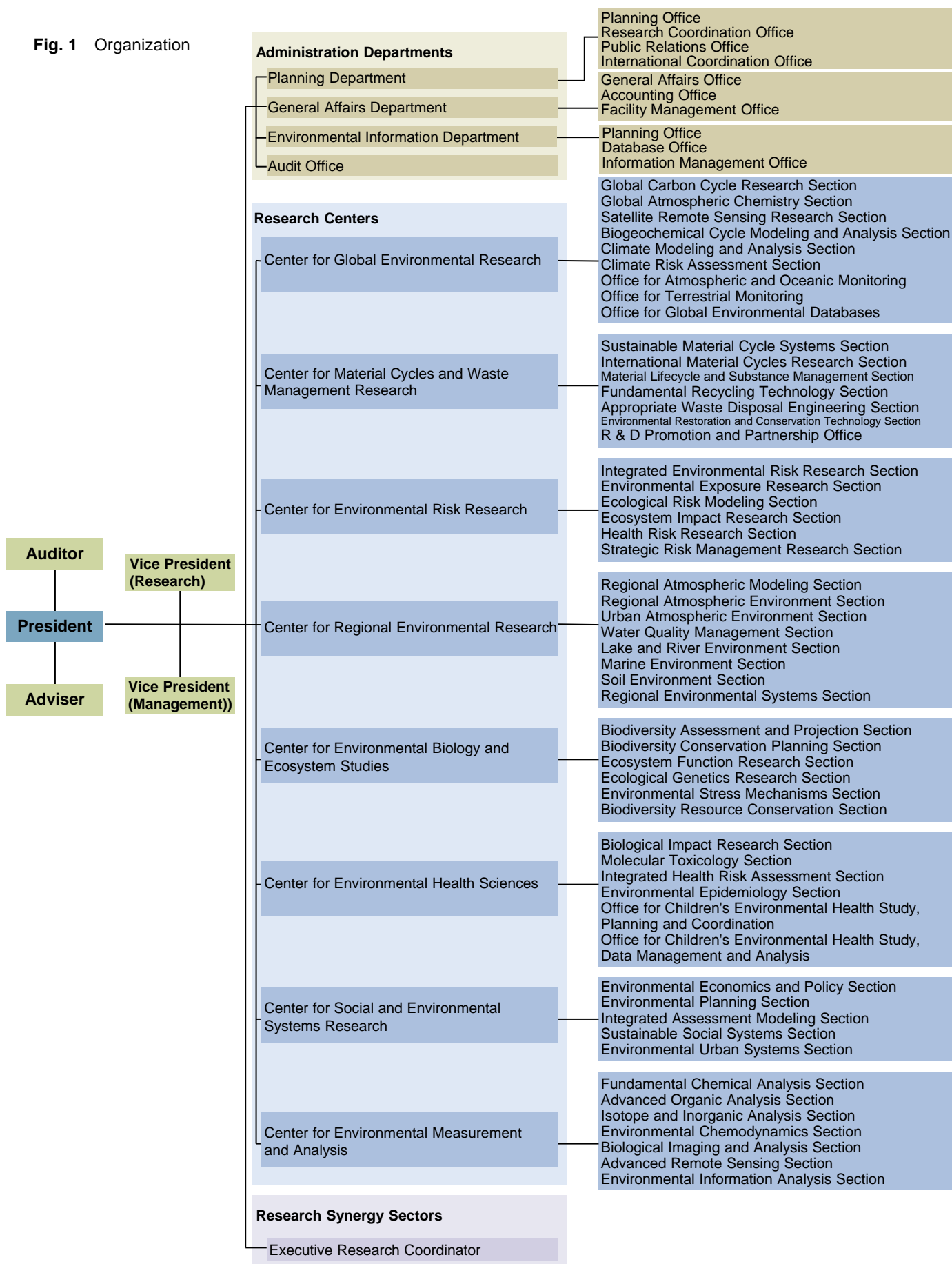President
October, 2012

Contents

During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established as part of the Japanese government in 1971, to develop measures to counteract serious problems associated with environmental pollution, such as Minamata disease, 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, with, for example, 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 at NIES of a Waste Management Research Division. April of that year also marked NIES' becoming an incorporated administrative agency, giving it a degree of independence from the national government. The change in the administrative status of the institute allowed more prompt and flexible responses to the demands of society. At the same time, NIES prepared a five-year (2001–2005) plan that corresponded to the objectives of the Ministry of the Environment.

The third five-year plan (2011-2015) was adopted in 2011, proceeding on from the second five-year plan (2006-2010). Eight pillar fields of environmental research are identified and the research centers to be responsible for these areas are specified (Fig. 1). At the same time, ten research programs are designated, with research now developing with an emphasis on the tying-up of these different fields. In order to further these research activities, NIES uses its' many external experimental and research facilities, such as Lake Kasumigaura Water Research Laboratory, Fuji Hokuroku Flux Observation Site, and Global Environmental Monitoring Stations in Hateruma and Cape Ochi-ishi. NIES also continues to engage in scientific research on environmental issues while actively pursuing ties, via joint research, with many institutions not only in Japan but also overseas, with an emphasis on those in Asia.

Fig. 1 Organization

Administration Departments
- Planning Department
  - Planning Office
  - Research Coordination Office
  - Public Relations Office
  - International Coordination Office
- General Affairs Department
  - General Affairs Office
  - Accounting Office
  - Facility Management Office
- Environmental Information Department
  - Planning Office
  - Database Office
  - Information Management Office
- Audit Office

Research Centers

- Center for Global Environmental Research
  - Global Carbon Cycle Research Section
  - Global Atmospheric Chemistry Section
  - Satellite Remote Sensing Research Section
  - Biogeochemical Cycle Modeling and Analysis Section
  - Climate Modeling and Analysis Section
  - Climate Risk Assessment Section
  - Office for Atmospheric and Oceanic Monitoring
  - Office for Terrestrial Monitoring
  - Office for Global Environmental Databases

- Center for Material Cycles and Waste Management Research
  - Sustainable Material Cycle Systems Section
  - International Material Cycles Research Section
  - Material Lifecycle and Substance Management Section
  - Fundamental Recycling Technology Section
  - Appropriate Waste Disposal Engineering Section
  - Environmental Restoration and Conservation Technology Section
  - R & D Promotion and Partnership Office

- Center for Environmental Risk Research
  - Integrated Environmental Risk Research Section
  - Environmental Exposure Research Section
  - Ecological Risk Modeling Section
  - Ecosystem Impact Research Section
  - Health Risk Research Section
  - Strategic Risk Management Research Section

- Center for Regional Environmental Research
  - 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
  - Regional Environmental Systems Section

- Center for Environmental Biology and Ecosystem Studies
  - Biodiversity Assessment and Projection Section
  - Biodiversity Conservation Planning Section
  - Ecosystem Function Research Section
  - Ecological Genetics Research Section
  - Environmental Stress Mechanisms Section
  - Biodiversity Resource Conservation Section

- Center for Environmental Health Sciences
  - Biological Impact Research Section
  - Molecular Toxicology Section
  - Integrated Health Risk Assessment Section
  - Environmental Epidemiology Section
  - Office for Children's Environmental Health Study, Planning and Coordination
  - Office for Children's Environmental Health Study, Data Management and Analysis

- Center for Social and Environmental Systems Research
  - Environmental Economics and Policy Section
  - Environmental Planning Section
  - Integrated Assessment Modeling Section
  - Sustainable Social Systems Section
  - Environmental Urban Systems Section

- Center for Environmental Measurement and Analysis
  - Fundamental Chemical Analysis Section
  - Advanced Organic Analysis Section
  - Isotope and Inorganic Analysis Section
  - Environmental Chemodynamics Section
  - Biological Imaging and Analysis Section
  - Advanced Remote Sensing Section
  - Environmental Information Analysis Section

Research Synergy Sectors
- Executive Research Coordinator

Auditor

Vice President (Research)

President

Adviser

Vice President (Management))

In relation to the Great East Japan Earthquake of March 11, 2011, we have provided our expertise and carried out studies towards finding measures to deal with disaster and radioactively contaminated waste, thus contributing to recovery and restoration for the disaster zone. Also, we have made diligent efforts towards the promotion of research aimed at the understanding and elucidation of the actual situation, and clarifying the movement of radioactive substances through the environment.

Human Resources & Budget

As of April 1, 2012, the total number of NIES regular permanent staff was 255 (including 6 foreign researchers). There were also 493 non-permanent researchers, including 55 foreign researchers (Table 1, Fig 2-4). The total budget for FY 2011 was 17,443 million yen (Table 2).

Table 1 Number of Permanent Staff

Research Centers	198	77.6%
Administration	52	20.4%
Executive	5	2.0%
Total	255	100%

(As of April 1, 2012)

Table 2 Budget for the Third Medium-Term Plan

(Unit: million yen)

	Category	2011-2015 Budget (5 years)	Fiscal 2011 Budget
Revenues	Grant for Operating Costs	68,320	13,523
	Subsidies for Facilities	1,540	263
	Commissioned Work	18,057	3,611
	Others	147	46
	Total	88,064	17,443
Expenditures	Project Costs	50,918	10,042
	Facility Improvements	1,540	263
	Expenses for Commissioned Work	18,057	3,611
	Personnel Expenses	15,316	3,053
	General Administrative Expenses	2,231	474
	Total	88,064	17,443

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

Human Resources

Executives — 5

Administration Departments — 52

198(6) — Research Centers
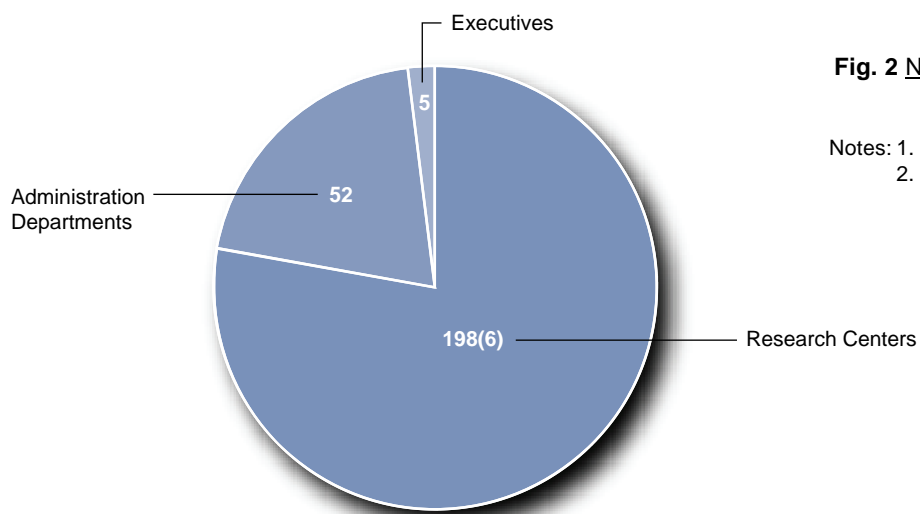
Fig. 2 Number of Permanent Staff
255 (6)

Notes: 1. Data is as of April 1, 2012.
2. Figures in parentheses indicate number of foreign researchers.

Sciences — 2.1%
Economics — 1.1%
Fisheries Sciences — 1.6%
Pharmaceutical Sciences — 3.2%
Medical Sciences — 6.3%
Agricultural Sciences — 12.6%
Engineering — 33.2%
0.5% — Law
0.5% — Veterinary Medicine
38.9% — Basic Sciences (Physics, Chemistry, Biology)
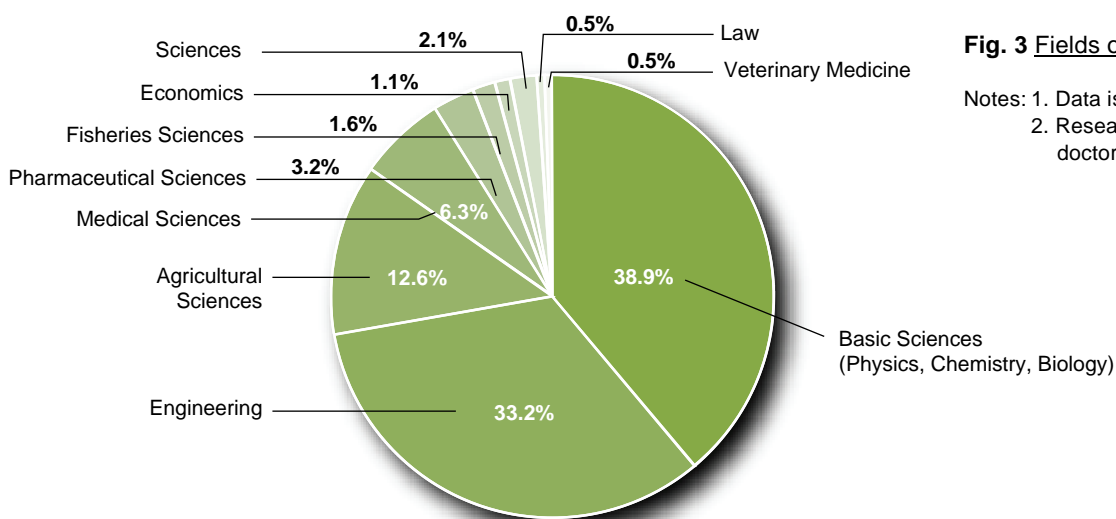
Fig. 3 Fields of Expertise

Notes: 1. Data is as of April 1, 2012.
2. Researchers holding doctorates 96.3%.

Senior Visiting Researchers — 9
Collaborative Researchers — 71(15)
Research Students — 86(15)
Contract Researchers — 135(19)
192(6) — Visiting Researchers
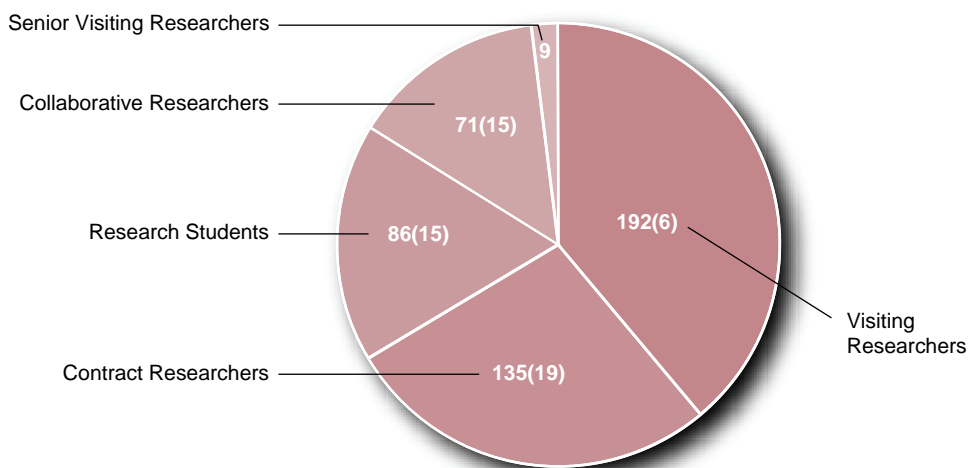
Fig. 4 Number of Visiting Researchers, etc
493 (55)

Notes: 1. Data for "Contract Researchers" is as of March 31, 2012. (Data for Fellows, Research Associates, Junior Research Associates and Research Assistants reflects the total number accepted in FY2011).
2. Figures in parentheses indicate number of foreign researchers.

Center for Global Environmental Research
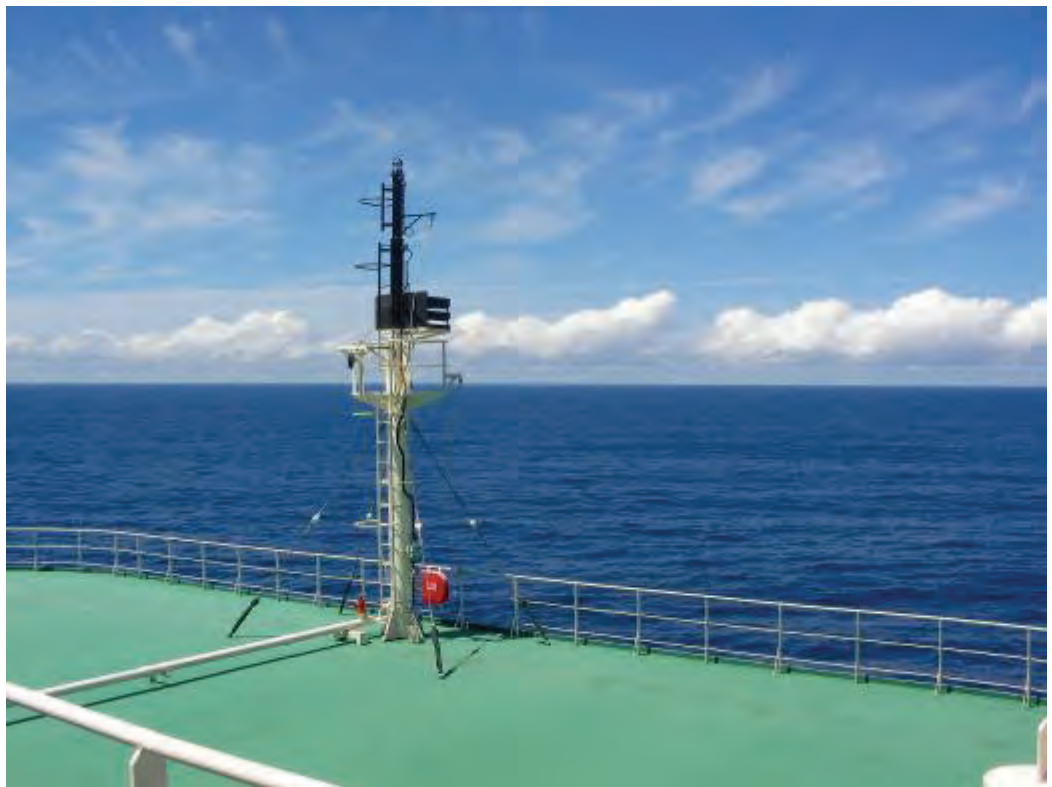
Because the ocean plays an important role in global warming, enhancement of ocean observation networks is a crucial issue. Continuous observations of greenhouse gases over the Pacific Ocean are performed onboard regular-service cargo ships by the Center for Global Environmental Research.

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, global warming, which is caused by increasing anthropogenic greenhouse gas (GHG) amount in the atmosphere, as well as its consequences, such as climate change and changes in the stratospheric ozone layer, have serious impacts on all ecosystems, including on humans.

Considering the scale and seriousness of the predicted impacts, it is indispensable that we take measures to conserve the global environment in order to create sustainable societies. Because it takes a relatively long time for environmental impacts on human activities to start to manifest themselves, it is essential that we take a long-term perspective and recognize the importance of mid- and long-term continuous research.

Therefore, on the basis of an accurate understanding of present 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. In cooperation with other research centers, CGER implements climate change research with a special emphasis on observing and clarifying global variation of GHGs in the atmosphere. It also aims to clarify historical climate change and predict future change, and it 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 prediction accuracy of changes in future sink strength. With regard to international climate policies, the development of risk management strategies on a global scale has become a major issue. At the same time, it is acknowledged that, to achieve a low-carbon society, each country must reduce its GHG emissions. However, important issues such as policy options and international cooperation remain unresolved. An important objective of the Climate Change Research Program 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 clarify the characteristics of 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 by using ground-based observation sites, ships, aircraft, and satellites. We are also seeking to provide the scientific knowledge needed to preserve natural GHG sinks.

The debate on targets of climate change countermeasures and the pathways leading to these targets is an issue of social decision-making in risk management. 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 ecosystems conservation risks. We are also examining risk-management options and risk-management strategies in the context of public risk awareness.

Below, we present information on several of CGER's research activities in FY 2011.

Multi-platform integration of GHG observations

This project focused on analyzing global GHG fluxes and their long-term variation. To estimate regional fluxes in GHGs we used two kinds of approach, namely top-down and bottom-up. The top-down approach consists of GHG observations from multiple platforms, including a satellite (GOSAT) and inverse modeling. The bottom-up approach uses GHG flux observation at terrestrial sites and over the ocean. The GHGs targeted were not only CO_2 but also CH_4, N_2O, halocarbons, O_3, and SF_6. However, observations for other, related gases (CO, O_2, H_2) were sometimes performed to characterize GHG behavior in the atmosphere. The contents of isotopes such as ^{13}C and ^{14}C in GHGs were also used in this project to determine GHG origin and the contribution of various fluxes, such as biogenic, oceanic, or anthropogenic.

GOSAT is used to observe column concentrations of CO_2 and CH_4 globally. Although the observable area is limited to places where the sky is clear, we can obtain new data over areas in China, West Asia, Africa, and South America where we have obtained few GHG data from ground-based monitoring stations. From our datasets, we tried to analyze the distribution of CO_2 flux over 64 regions of the globe by using the inverse modeling technique developed by CGER. We found that the use of GOSAT data, in addition to the well-known background site data, generally decreased the uncertainty of CO_2 flux estimation.

Although GOSAT covers large areas, its measurement precision and frequency are not consistently high. Therefore, the use of other, in-situ, observational data obtained from monitoring stations in Japan (Hateruma, Ochi-ishi, and Mt. Fuji), from cooperating sites in foreign countries (Nainital in India, the Danum Valley in Malaysia, Guiyang in China, and Hawaii and Siberia), from three cargo ships operating over the Pacific and the South East Asian region, and from commercial (Japan Airlines) aircraft was essential to cover important regions, as well as to obtain vertical profile information and verify the precision of the GOSAT data. This year we tried to develop a new site in Bangladesh and one more cargo ship route for the East Asian area so that we could cover a larger area of Asia.

To integrate the data from these various observation points (Fig.1), we initiated a new database system that will help to analyze global source and sink distributions and the temporal variability of GHGs.

Fig. 1 Distribution of GOSAT column CO_2 comcentrations in January 2011 and locations of observation sites and routes. These data will be integrated for use in inverse modeling to estimate regional fluxes.
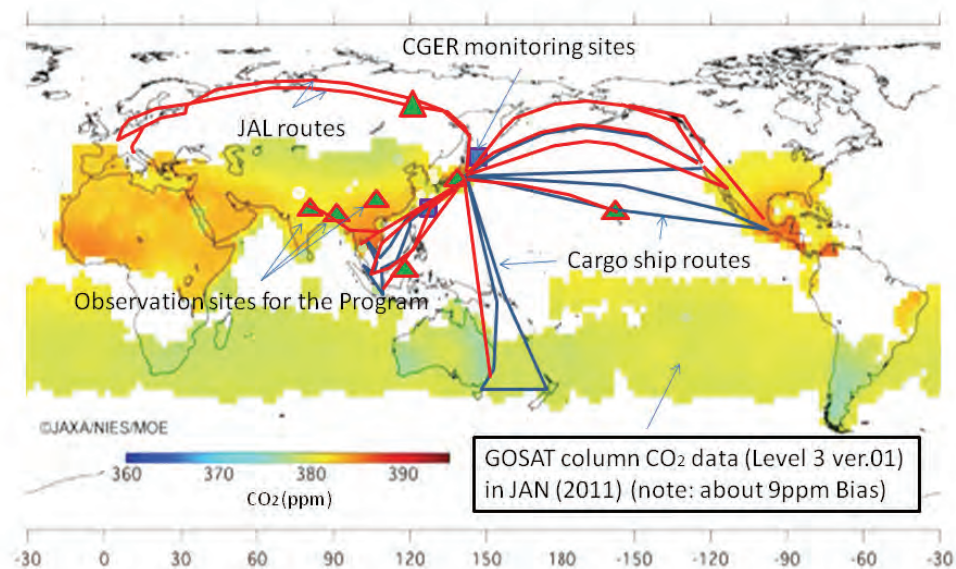

Assessment of agricultural impacts of climate change in the context of the uncertainty of climate projections

Climate change due to anthropogenic GHG emissions will have a large effect on future crop yields, and this risk needs to be managed at various scales through mitigation and adaptation measures. Some regions are predicted to experience large decreases in crop yield in the future due to climate change. Therefore, through quantitative assessment of changes in crop yield, we need to develop an understanding of the regions vulnerable to climate change. To evaluate changes in crop yield with future climate change, climate projections are input into a crop yield model. However, uncertainty is present in the General Circulation Model (GCM) climate projections developed by research institutes around the world. In light of the uncertainty of these climate projections, we estimated changes in crop yield so as to gain an understanding of the plausible range of impacts of climate change. Here, we present projected changes in maize yield as an example of our results.

To evaluate uncertainty in the climate projections, we used climate projections from 19 GCMs evaluated in the Fourth Assessment Report (AR4) of the IPCC (Intergovernmental Panel on Climate Change). Because uncertainty factors are included in the climate projections, we quantitatively estimated the range of uncertainties derived from the choice of GHG emission scenarios and climate

models. We found that the range of estimates derived from the GCM climate projections was much larger than that derived from the emission scenarios. To quantify the changes in maize yield on a global scale, we calculated maize production in four simulation periods (the 1990s, 2020s, 2050s, and 2080s) by inputting climate projections into the GAEZ (Global Agro-Ecological Zones) model. The rate of maize yield change and the associated uncertainty range for 49 GCM climate projections under three different SRES (Special Report on Emissions Scenarios) scenarios (A1B, A2, and B1) are shown in Figure 2. There was a large range of estimates in the projected results under the A2 scenario in the 2080s, with a reduction in yield of 52% in the GFDL-CM2.0 projection and an increase of 10% in the GISS-ER projection. The results suggest that the climate model needs to be chosen carefully in any evaluation of the impact of climate change and of adaptation.

Fig. 2 Rates of maize yield change and uncertainty under three SRES scenarios
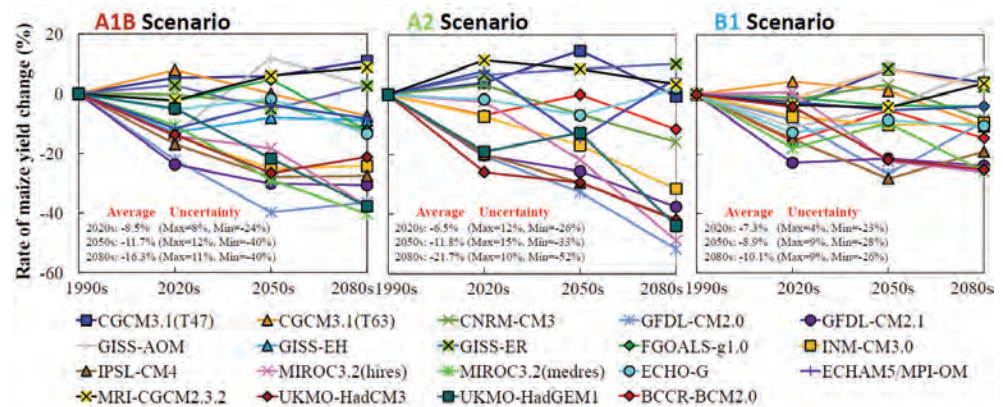
Comprehensive climate policy assessment and development of visions and scenarios towards a low-carbon society

This study has been restarted as part of the third NIES five-year plan. There are three sub-themes: (1) scenarios and implementation strategies for a low-carbon society in Asia; (2) quantitative assessment of climate change mitigation policies in Japan and around the world; and (3) study of international institutions and negotiation processes for the development of a low-carbon society. Our continuing aim is to provide scientific knowledge from the viewpoints 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.

We used a global model to analyze the feasibility of a low-carbon society scenario in which global GHG emissions in 2050 are reduced by 50% from the 1990 level. The global model simulation results showed that the low-carbon-society scenario is achievable, but that the associated carbon price is currently still high. In addition, we evaluated mitigation actions for 15 targeted countries or regions in detail by using country-specific models. The scenarios for the targeted Asian countries took the specific conditions in those countries into consideration, namely the existing GHG emission structure, the economic status, and the political, cultural, and social background. For our comprehensive analysis,

these studies were implemented in collaboration with local low-carbon-society researchers in several developing countries. The effective policy package and measures identified in each country's study were quite diverse, and we concluded that any countermeasures should be well designed so as to suit local conditions.

By improving a top-down computable general equilibrium model and a bottom-up technology selection model on a global scale with multiple regions and sectors in the Asia-Pacific Integrated Model (AIM), we analyzed GHG mitigation options and their economic impact. We also evaluated global and regional GHG emission pathways toward the targets of long-term climate change stabilization and 50% global GHG emissions reduction by 2050. The top-down and bottom-up models were the AIM/CGE[Global] model and the AIM/Enduse[Global] model, respectively. We used the results in participating, together with various international institutes, in international projects on model comparison and contributing actively to international discussions on global emissions pathways toward the development of a low-carbon society. One of our outputs, which discussed a pathway for stabilization of radiative forcing at 6.0 W/m^2 by 2100, was published in an international journal together with other RCPs (representative concentration pathways).

We studied the post-2012 international framework for climate change mitigation by making a comparative analysis of the national climate change policies and policy-making processes of major countries, namely the USA, the EU, Russia, China, and India. The study concluded that multilateral negotiations are not likely to achieve an agreement on emission reduction targets for at least another few years. This is mainly because the largest two key players, the USA and China, have little incentive to accept such an agreement. The study developed four scenarios in which multilateral institutions regain their credibility so they can involve major countries in an agreement on climate change policies.

Long-term monitoring of GHGs and other trace gases

Atmospheric GHGs (e.g., CO_2, CH_4, and N_2O) and other chemical species (CO, NO_x, and SO_x) are monitored from various platforms to determine the long-term variations in the concentrations of these gases and their spatial distributions. We have two ground-based stations, at Hateruma Island (over 1000 km southwest of the Japanese mainland) and at Cape Ochi-ishi (in northeastern Hokkaido). Commercial ships operating between Japan and Australia, New Zealand, North America, and Asian countries are used to observe the latitudinal or longitudinal distributions of GHGs and the partial pressures of CO_2 in the surface waters of the Pacific. Routine samplings are conducted from aircraft over three sites in Siberia to measure the vertical distributions of GHGs. UV-A and UV-B on the ground are monitored, and real-time UV indexes obtained at 15 sites in Japan are available to the public via our web page. To detect the effects of global warming on the marine environment, the distributions of tropical reef corals and the DNA clades of the symbiotic algae zooxanthellae around Japan are monitored.

We have been observing annual mean CH_4 concentration profiles over a wetland

area near Surgut, in west Siberia, by aircraft; the values near the surface are obviously higher than those in the free troposphere (Fig. 3). This indicates that substantial amounts of CH_4 are emitted from the wetland to the atmosphere around Surgut. The averaged vertical differences in the observing period are 90 ppb between 7 and 0.5 km altitude and 60 ppb between 7 and 1 km. After an abrupt increase in annual mean CH_4 concentration from 1997 to 1998, the value was almost steady for 8 or 9 years. However, after 2006, CH_4 concentrations over Surgut started to increase again, not only in the atmospheric boundary layer near the surface but also in the free troposphere.

Fig. 3 Vertical profiles of annual mean CH_4 concentrations over Surgut, in west Siberia.
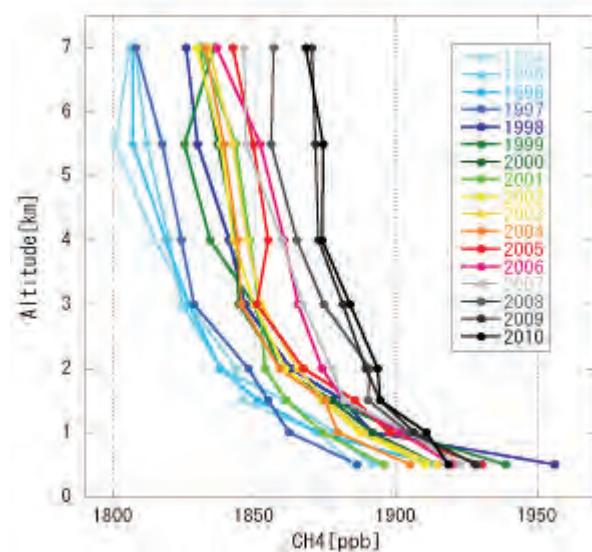
Carbon dioxide flux monitoring of terrestrial ecosystems

Long-term monitoring of carbon, water, and energy exchange between larch forests and the atmosphere, as well as of biological processes in these forests, has been conducted in larch forests in Japan to determine how the forests respond to climate change and how the responses depend on the process of recovery from natural and artificial disturbances. The Fuji Hokuroku Flux Observation Site is located in a mature larch forest at the foot of Mt. Fuji. Clear seasonal changes in carbon uptake were observed here and were related to the phenology of the larch trees. Continuous observation of the flux of CH_4, one of the most influential GHGs, has recently started over the forest canopy at the Fuji Hokuroku Site through application of the relaxed eddy accumulation (REA) method. The REA method was developed for those gases that could not be measured in the air at the high frequencies needed to apply the covariance measurement technique. The mechanism of seasonal and interannual change in CH_4 flux will be studied from the monitoring data obtained at this study site.

At the Teshio Carbon Cycle and Larch Growth (CC-LaG) Experiment Site in Hokkaido, 14 ha of forest was clear-cut and larch saplings were planted in 2003. The clear-cutting resulted in decreased photosynthesis and increased

decomposition of dead roots and soil organic carbon. It took 5 years for the annual carbon balance to stabilize.

Long-term monitoring of alpine vegetation began in 2011 to detect the influence of global warming on the phenology, production, and species distribution of alpine ecosystems. Two focused monitoring areas were selected after feasibility studies in the previous 2 years: one in the Japan North Alps extending over Nagano and Toyama prefectures, and the other on Mt. Rishiri in Hokkaido. Several observation points were selected in each area, and automatic digital camera systems were installed at every point to collect images representing day-to-day changes in snow area, leaf expansion, flowering, and leaf coloring on the slopes of the mountain. Image data are acquired in the laboratory by using a real-time data transmission system and broadband networks. Phenological changes at the start of the growing season have been clearly observed in response to the spring snowmelt.

Some of the data obtained from our terrestrial monitoring are available to the public on the CGER web page.

NIES GOSAT project

We continued processing GOSAT data at the NIES GOSAT Data Handling Facility, as well as online distribution of GOSAT data products to researchers and public users via the GOSAT User Interface Gateway (http://data.gosat.nies.go.jp/). In addition to the data products already made available to users, we newly disseminated the following data items: global reflectance distribution, which is obtained from the data of TANSO-CAI (Thermal And Near-infrared Sensor for carbon Observation – Cloud and Aerosol Imager) and is a CAI Level 3 product open to general users; the normalized difference vegetation index (NDVI), which is a CAI Level 3 product, released to registered researchers; and vertical profiles of CO_2 and CH_4, which are obtained with TANSO-FTS TIR (-Fourier Transform Spectrometer Thermal Infra-Red) band, and are FTS Level 2 products available to general users.

We carried on with our major research tasks of improving our data retrieval algorithms, evaluating GOSAT data products against reference data (validation), and estimating surface CO_2 fluxes. Our continued efforts to improve the data retrieval algorithm led to completion of the second version of the algorithm (Ver. 02) for the TANSO-FTS SWIR (Short-Wavelength Infra-Red) Level 2 product. We validated the data by comparing column-averaged concentrations with reference values obtained with ground-based high-resolution FTSs participating in TCCON (Total Carbon Column Observing Network) and with *in-situ* instruments installed on aircraft used in CONTRAIL (Comprehensive Observation Network for TRace gases by AIrLiner), the US NOAA (National Oceanic and Atmospheric Administration) aircraft program, and the NIES airborne sampling project. We also evaluated the contribution that the GOSAT-based column CO_2 data can make to reducing the uncertainty associated with estimates of monthly regional CO_2 fluxes. We found that complementing ground-based network data with the GOSAT data could lower the flux uncertainty

by as much as about 50% (Fig. 4).

Fig. 4 Rates of reduction (in %) of the uncertainty of monthly surface CO_2 flux estimates, obtained by adding GOSAT column CO_2 concentration data to the dataset of GLOBALVIEW observations.
The values shown are annual means for the period between June 2009 and May 2010.
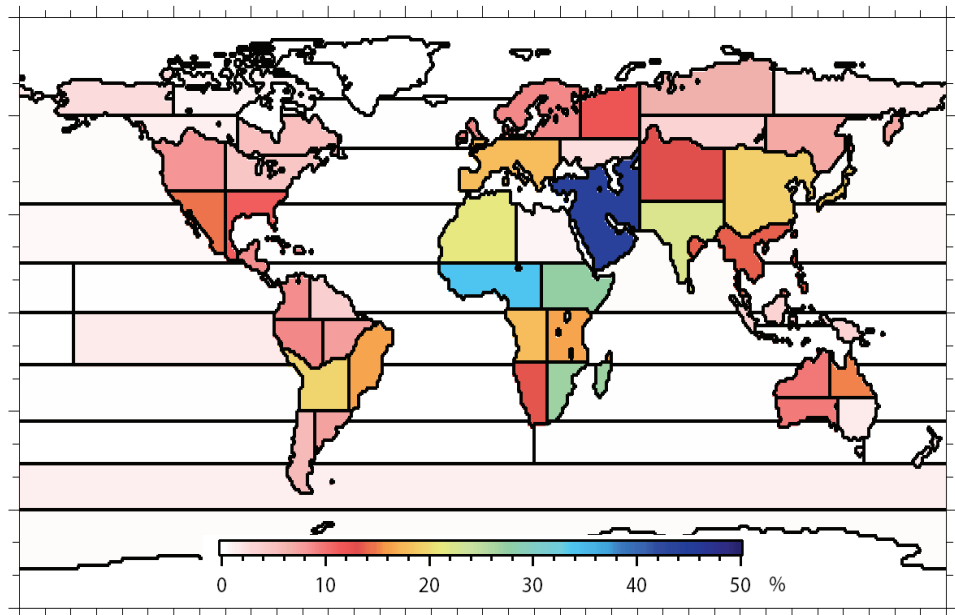
Center for Material Cycles and Waste Management Research
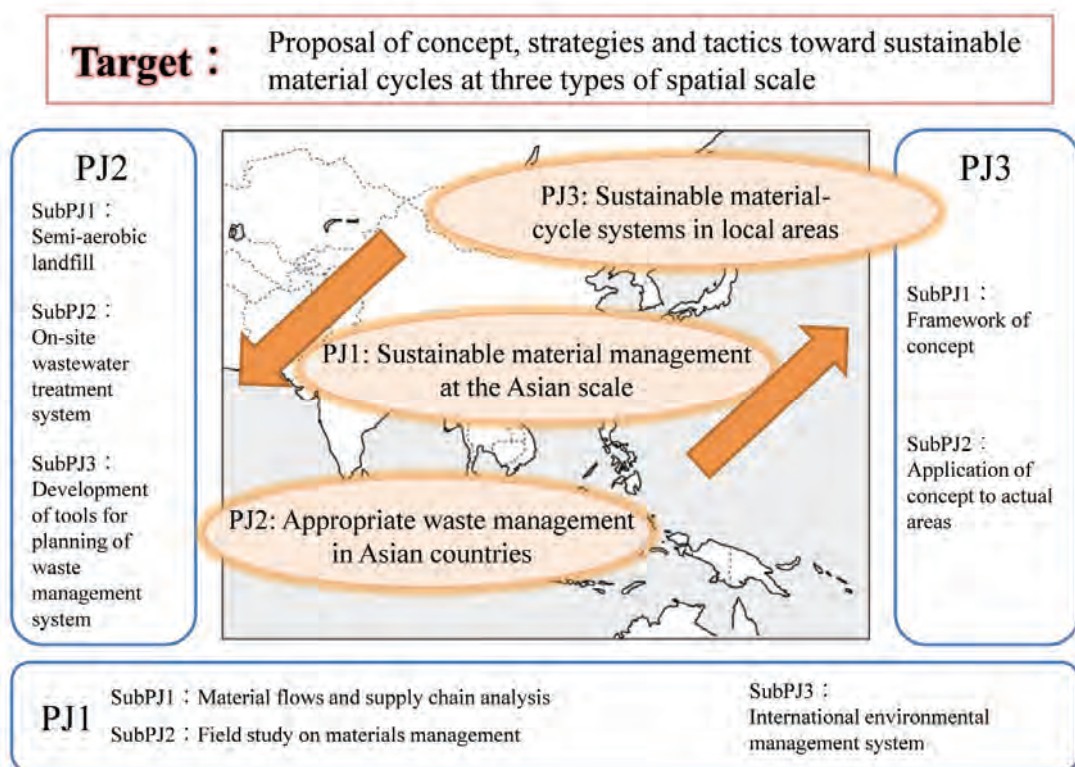
Research Program on Sustainable Material Cycles
(FY 2011–2016)

Since its foundation in 2001, the Center for Material Cycles and Waste Management Research has aimed to realize a society with desirable material cycles, i.e., reduced use of natural resources, reduced generation of waste, increased recycling of materials, and appropriate waste management. In accordance with the third 5-year plan of NIES (covering the period 2011–2015), the center is playing a major role in promoting a research program on "Sustainable Material Cycles," which comprises the three research projects. It is also conducting the 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 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) Appropriate management of materials with hazard and resource potential in harmony with international material cycles (Research project 1)

Understanding international material flows and system analysis

Figure 1 is a visual representation of the flows of iron embedded in Japanese (a) exports and (b) imports, by commodity category. The export flows consist of 0.5×10^3 t of ore, 27.7×10^6 t of iron and steel materials, 12.9×10^6 t of products, and 2.9×10^6 t of scrap. The top five countries and regions receiving iron from Japan are South Korea (7.7×10^6 t), the USA (6.0×10^6 t), China (5.1×10^6 t), Taiwan (3.2×10^6 t), and Thailand (3×10^6 t). The remaining 18.9×10^6 t is distributed to other countries and regions. In terms of the iron flows in Japanese imports, Australia, Brazil, India, the Philippines, and South Africa are the major countries supplying iron to Japan. The total amount of iron embedded in imports is estimated at 87.7×10^6 t; of this, 88.9% is in the form of iron ore. Iron processing and trade in Japan are characterized by the import of iron ore as a raw material from Australia and Brazil, followed by its processing and export to Asia as steel materials and to the USA as steel materials and automobiles.

Fig. 1 Flows of iron embedded in Japanese exports and imports in 2000. X_{eri} is the amount of substance e embedded in trade item i exported to country r.
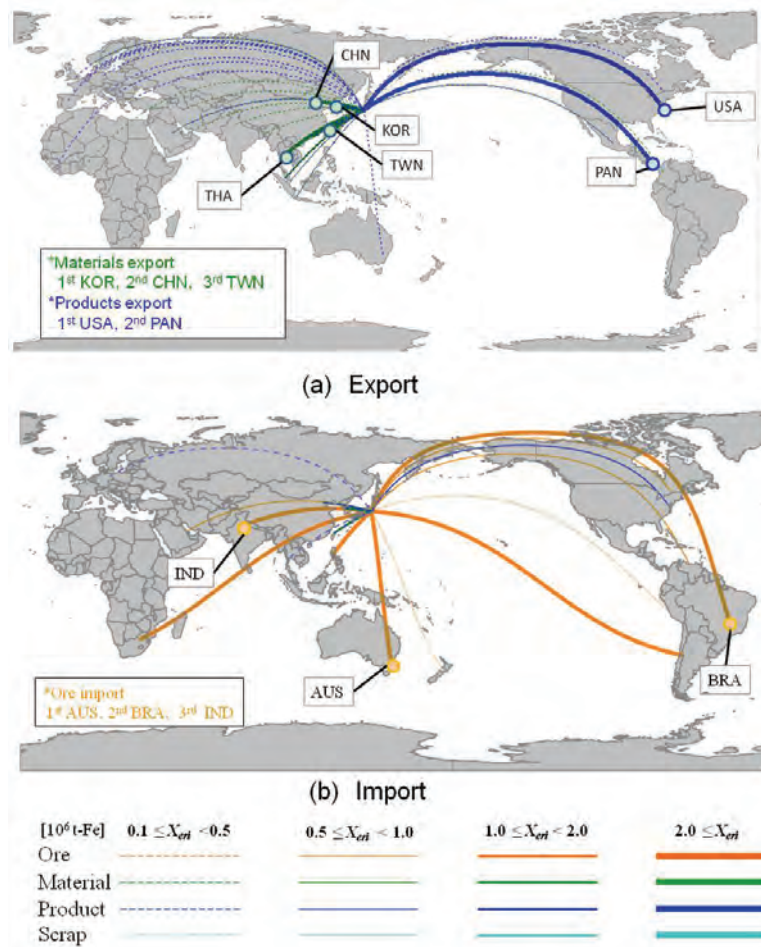
Field study of product and material cycles for managing resources and chemical risk

From our field study around Metro Manila in the Philippines, we sampled and quantified the concentrations, enrichment factors, and hazard indicators of 11 metals (Ag, As, Cd, Co, Cu, Fe, In, Mn, Ni, Pb, and Zn) in soil and dust surface matrices from formal and informal electronic waste (e-waste) recycling sites. To compile our data we referred to soil guidelines and previous data from various e-waste recycling sites in Asia. Surface dust from e-waste recycling sites had higher levels of metal contamination than did surface soil. Comparison of formal and informal e-waste recycling sites revealed differences in specific contaminants. Surface dust from formal recycling sites contained a mixture of metals that are considered serious pollutants (Ni, Cu, Pb, and Zn) and Cd (at modest levels) and quite high levels of enrichment metals (Ag and In) and crust-derived metals (As, Co, Fe, and Mn). In surface soils from informal recycling sites, the concentrations of Cd, Co, Cu, Mn, Ni, Pb, and Zn were similar to those at other Asian informal recycling sites. Dust from formal recycling sites posed significantly greater health risks than the other matrices ($p < 0.005$), excluding dust from informal recycling sites. Workers exposed to dust at formal recycling sites should therefore protect

themselves from hazardous metals (e.g. Pb and Cu). We also found a high health risk to children ingesting surface matrices from informal e-waste recycling sites.

Proposing management measures toward an international sound material-cycle society

We reviewed various ESM (environmentally sound management) standards for e-waste in the guidelines related to the Basel Convention and other national regulations. These standards specify occupational health and safety and monitoring. In most guidelines, batteries and printed circuit board were deemed hazardous components to be removed before mechanical recycling; downstream management of these components after dismantling was specified only in advanced guidelines by manufacturers and others. Our investigation of secondhand goods and transactions by scrap dealers revealed that publicity and strict enforcement were important in controlling "invisible flows" as part of the management of e-waste export from Japan.

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

Development of a method of designing semi-aerobic landfill technologies appropriate for Asian countries

To refine our estimations of greenhouse gas (GHG) emissions from waste landfills managed semi-aerobically, we developed a GHG emission model that included the management of features such as oxygen concentration and moisture in the waste layers. Experimental test cells constructed at a landfill in Thailand were evaluated to explore semi-aerobic management in a tropical environment. Furthermore, a long-term management assessment revealed the competitive advantages of semi-aerobic landfills including leachate management in terms of water pollution, energy balance, GHG emissions, and operational costs.

Development of on-site wastewater treatment technologies for developing nations

We reviewed on-site liquid-waste treatment technologies installed in China, with particular focus on household biogas digesters (Fig. 2). The distribution of these facilities and the business structure and technical standards required to improve such on-site technologies were examined. A laboratory-scale experiment in biological desulfurization to develop a low-cost biogas-purification process was also conducted. We achieved effective operation and control of a low-cost biological gas-purification process under an appropriate O_2 to H_2S supply ratio. In addition, an algorithm for choosing appropriate liquid-waste technologies for Asian cities by using the characteristics of each region as parameters was developed, and successfully applied to actual Asian cities.

Fig. 2 Distribution and biogas production of household digesters in China.
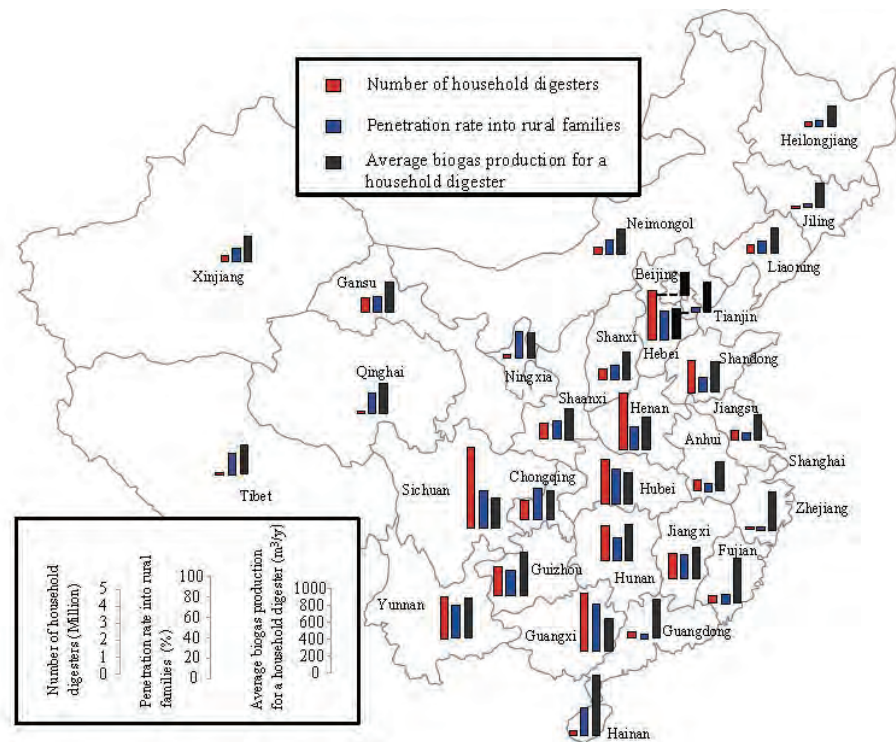
Development of tools for planning of waste management systems
Through various surveys conducted mainly in Vietnam, we accumulated reliable data on municipal solid waste management; such data are generally difficult to find in developing countries. The survey elucidated the physical composition (food, paper, plastics, etc.) and proximate composition (moisture, volatile matter, and ash contents) of household waste in Hanoi. We proposed a tool for use in selecting alternative waste treatment technologies; the tool shows the boundaries of the proximate composition applicable to each technology and the changes in composition according to each scenario for source separation of household waste. Source separation into combustible waste, non-combustible waste, and biodegradables increased the lower heating value of combustible waste. To elucidate the factors affecting waste separation at source, we conducted a questionnaire survey on source-separation activities by members of the public in the areas of Hanoi that we had used to model source-separation systems for organic and inorganic waste. The source-separation activities of community leaders influenced the separation activities of people living in the communities.

(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. In this project, we are investigating a framework for establishing material-cycle systems suited to various regional characteristics, such as various states of waste generation, types of existing industries, and relationships among various entities. We will also design proper material-cycle systems for several recyclable resources (including waste plastics,

biomass wastes, and used products containing critical metals) at the municipal, prefectural, regional, and national levels. The systems will be designed to minimize costs and environmental loads and to revitalize and promote regional economies by actively using and cultivating regional industries and other entities. The project aims to contribute to regional communities by designing regional systems. It also aims to contribute to science on material cycles by establishing methodologies for estimating appropriate geological scales for material cycles and formulating concepts for local use of these cycles.

In the first year of the project, we reviewed several cases of regional material cycles and identified factors that are key to regional societies, namely development of the local economy, a stable population in the region, and resident satisfaction. We collected the data required for assessing sound regional material cycle systems; these data covered such items as the profiles of regional industries and technologies, regional resources, and regional material flows. We tentatively categorized the parameters that could be used to reflect regional characteristics, and we discussed their importance in utilizing regional characteristics and the directions of regional material-cycle systems.

Designing a framework for constructing regionally appropriate material-cycle systems

We reviewed both domestic and foreign cases of regional development that focused on environmental aspects. The cases included those in Australia and Sweden. The results suggested that key factors for a regional society were development of the local economy, a stable population in the region, and resident satisfaction. "Distributed economy" was a concept related to this research project.

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

We started collecting the data required to design and assess sound regional material-cycle systems. These included data on the location and capacity of metal refinery plants in the Asian region, the amounts of biowaste generated, and the demand for recycled products made from these wastes. Data on refinery plants are part of the technological profiles of regions, whereas data on wastes and recycled products are part of the resource profiles; both profiles will serve as basic information for designing regional material-cycle systems. We will continue to collect such data until FY 2013. In a case study of Kochi Prefecture, we created a physical input–output table of biomass resources and wastes associated with the agricultural, forestry, and livestock industries, describing complex material flows from resource extraction through consumption to waste disposal (Fig. 3).

Fig. 3 Perceived structure of biomass recycling and activation of a local community
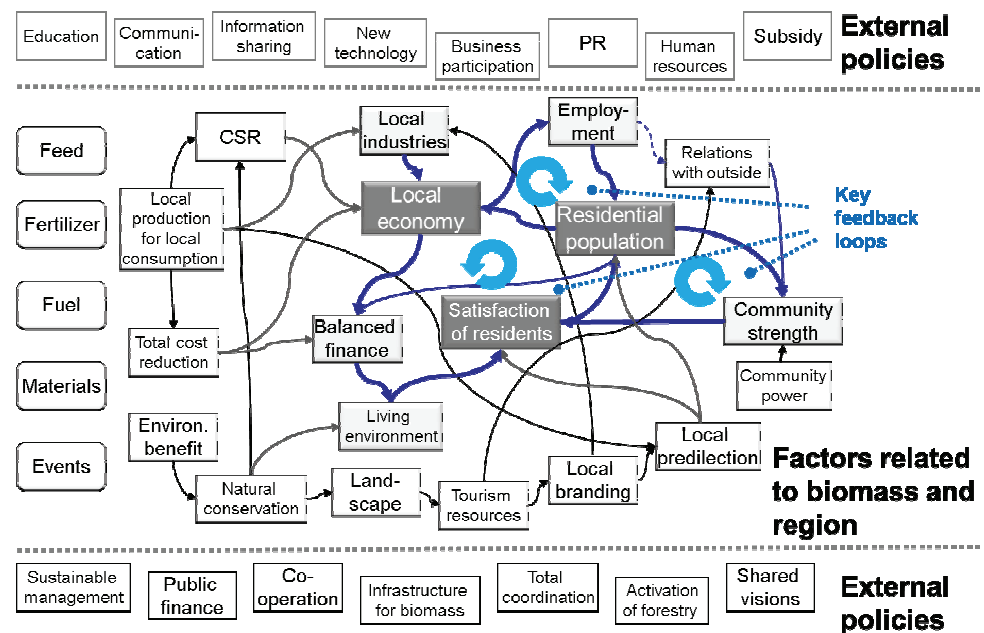
2. Waste management research needed in response to national policies

(1) Evaluation of waste incineration systems and development of an energy recovery technology

We conducted questionnaire and operational data surveys regarding municipal solid waste (MSW) incineration plants to investigate how the power generation performance of plants in eastern Japan changed in 2011 in response to the power shortages from the serious Fukushima nuclear power plant accident in the same year. The results showed that the average amount of power generated was 1.25 times the amount in 2010, and that the increase was obtained by the efforts of individual plants, for example, by increasing MSW incineration last summer.

We also conducted a biomass gasification study to develop an efficient gas-recovery process and further gas conversion processes. To increase the energy density of the producer gas, we investigated gas conversion by using the reverse water-gas shift (RWGS) reaction. Well-dispersed (monodispersed) NiO/SBA-15 with a large amount of NiO obtained by the direct synthesis method was used as a catalyst. NiO/SBA-15 catalysts exhibited excellent efficiency and selectivity in the reduction of CO_2 to CO by the RWGS reaction. The CO_2 conversion rate increased as the temperature increased, regardless of the NiO amount. However, CO selectivity was influenced by the amount of NiO and the synthesis method. We intend to continue this study to improve the technical efficiency and performance of the process.

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

To develop the waste management strategies needed for a future advanced recycling society, we need to classify wastes by resource value, environmental load, and treatment cost. We need to develop new technologies and systems for

controlling the quality of wastes that are to be recycled or treated, and for final disposal, by managing material flows and setting up new types of final disposal. In this study, we evaluated new concepts of landfill. First, for stockpiling-type landfills, we proposed business models to maximize the value of stocked wastes. We fully assessed the feasibility and suitability of land-reclamation-type landfills and enhanced bio-stabilization landfills by using various methods such as laboratory- and pilot-scale experiments, field investigations, and literature reviews. In addition, after the Fukushima nuclear power plant accident, we recommended that radio-contaminated ash from waste incinerators should be disposed of at specific landfill sites after strict measures had been taken to prevent contamination of the local environment, and we proposed a method for calculating the rates of radio-contaminated ash generation in the next decades in eastern Japan. Our numerical analysis revealed that reduction of the rate of infiltration of rainwater into landfill sites is the most critical factor to minimize the rate of leaching of radioactive cesium from radio-contaminated ash.

(3) Establishment of appropriate measures to combat domestic liquid-waste and GHG emissions

We experimented with GHG emission reduction in *johkasou* (household wastewater systems). The results of a full-scale *johkasou* experiment showed that CH_4 and N_2O concentrations varied over the day in response to changes in the timing of inflow of domestic wastewater. We also found that anaerobic–aerobic circulation can reduce GHG emissions. Drawing off excess sludge did not have a strong impact on GHG emissions. On the basis of these results, we are implementing on-site investigations of emission factors in decentralized domestic wastewater treatment facilities such as *johkasou*.

In addition, we experimented with using a floating hydroponic aquatic plant system to purify polluted river and lake waters. The results showed that rates of reduction of BOD (biochemical oxygen demand), COD (chemical oxygen demand) and nitrogen and phosphorus levels were highest with a hybrid system of hydroponic plants, submerged plants, and aquatic animals. We also conducted hydrothermal treatment using waste biomass such as seaweed, sewage sludge, and rice husk. Acetate production was the highest using rice husk, followed by sewage sludge and seaweed. The elution behavior of inorganic components was related to the contents of the waste biomass.

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

To ensure proper management and treatment of disaster wastes, we studied ways of preventing fires in temporary depots for such wastes. We investigated more than 100 temporary depots and proposed fire-prevention measures. We also studied a method of screening for asbestos in disaster wastes and damaged buildings. We examined a rapid screening method that used a polarized light microscope. This method was reliable and faster than the conventional JIS

method using an X-ray diffractometer. We then applied the method to the mapping of damaged buildings containing asbestos as a building material.

In another study of a treatment technology for POPs (persistent organic pollutants), we performed experimental combustion of organofluorine products. Total fluorine and hydrogen fluoride were completely removed from the exhaust gas during the combustion and gas-treatment processes. Because the lead in CRT (cathode ray tube) glass could disrupt recycling efforts, we also studied a technology for removing lead from this glass. Moreover, we confirmed the capability of the chlorination–volatilization process and the usability of polyvinyl chloride wastes as a chlorine source.

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

We finished developing a basic concept of environmental safety quality and ways of inspecting for it in various recycled materials used in construction, and we also developed procedures for application to each material. We performed a single-batch leaching test of steel slag water in which the pH was maintained at 8 or 9 for 70 days using sea and nitric acid in the presence of humic substances. We proved that the concentrations of toxic metals in the leachate were quite low throughout the experiment.

In our quality evaluations of recycled polyethylene resin, generation of a polar functional group was detected using infrared spectrophotometry. Also, generation of aliphatic aldehyde and alcohols was detected by using heat desorption analysis. These analytical methods proved to be effective tools in the quality evaluation of recycled synthetic resins.

3. Promotion of seed and fundamental research
(1) Systems approach and policy study of life-cycle resource management

We have started compiling a database on international material flows to analyze the structural characteristics of the global supply chain associated with Japanese resource use. The supply chain will be identified by using a global link input–output model. Data on the resource reserves, production capacity, and state of resource policy in resource-supplying countries were investigated. We also investigated two EPR (extended producer responsibility)/waste management programs in California as a case study of EPR application in North America. We found that a common feature of these programs was that the involvement of the state government was small and producers and municipalities could use their discretion in the establishment of recycling and waste management systems. We categorized types of public involvement in recycling and waste management in consideration of two stakeholders—producer and municipality—and examined public involvement further. For advancing environmental product policy, we focused on multiple-function products (MFPs) and identified a variety of challenges and risks for achieving sustainable consumption and production as well as a fair consumer society and pursuing universal design of products. We then examined product standards for such MFPs and elucidated the advantages

and limitations of five approaches to standard-setting for MFPs. 2R (reduce and reuse) policies in foreign countries were also reviewed. Parts of these studies were conducted in collaboration with researchers from IIIEE (the International Institute for Industrial Environmental Economics), at Lund University in Sweden, under an MOU (Memorandum of Understanding) agreement.

(2) Study of fundamental technologies required for material cycles and waste treatment

We developed chemical analysis methods to explore feedstock materials or to identify hazardous chemicals in various wastes and circulative resources. Moreover, we developed a panel of *in vitro* bioassays for screening important toxicities, such as reproductive toxicity, as part of an overall toxicty evaluation system. We measured the vapor pressures of flame retardants such as aromatic phosphate esters and the viscosities of oils and fats. The environmental fate of novel brominated flame retardants (BFRs) was evaluated. Furthermore, we proposed physicochemical properties of these novel BFRs to be measured in the future. We collected and analyzed information on the current status of crushing and sorting facilities for bulky waste so as to increase the rates of resource recovery from the waste. We also optimized an acid-washing technology for upgrading trap grease to save on resources. The quality of the upgraded grease was examined with a view to using the grease to replace heavy fossil fuels.

(3) Strategic establishment of information research fundamentals for resource circulation and waste management

We intend to create databases as research fundamentals for resource circulation and waste management. This collection of data is aimed at guiding future studies on resource use and waste management in Japan and Asia. To establish a database on global materials circulation, we examined categories of commodities and collected data on the concentrations of elements in each commodity so as to develop a way of extracting information on the amount of transboundary movement of resources from trade statistics. We also gathered information on the rules for sorting WEEE (waste electrical and electronic equipment) and waste batteries from about 780 municipalities (covering 83% of the entire population) to compile a database on municipal waste management policy. We continued to compile data on the metal contents of electronic products, and we examined concepts for a database of waste management in Asia.

Center for Environmental Risk Research

Activities of a reference laboratory for ecological hazard assessment.
Our projects are aimed at developing the functions provided by our core laboratory, which establishes standards and criteria for eco-toxicity testing in Japan and abroad.
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Our research in the field of environmental risk is focused on chemical substances in the environment. To advance the evaluation and management of environmental risks, we concentrate our efforts on a number of issues. We develop ecological impact assessment methods; develop techniques for predicting the toxicity of chemical substances by using theoretical chemistry and information sciences; clarify the routes and dynamics of exposure to chemicals and develop exposure evaluation methods; develop techniques for ascertaining the status and effects of exposure to chemical substances in the environment; study mechanisms for assessing and develop ways of evaluating ecological risks; study mechanisms and methods for evaluating adverse effects on human health and assessing health risks; examine policies and management relating to environmental risks; study risk communication; and gather information relating to environmental risks.

In FY 2011, to address immediate and priority issues, the Center for Environmental Risk Research started a key research program on innovation in the evaluation and management of chemical substances. We also began research projects to develop infrastructure for environmental research, which requires a long-term effort, and for fundamental research to support environmental action plans, which takes policy needs into account. In addition, we continued our other fundamental research and practical environmental risk assessment activities.

Research Program on Risk Assessment and Control of Environmental Chemicals

In recent years, the management of chemical substances has incorporated assessments of their impact on living organisms in the environment. However, the idea of ecosystem protection is not fully entrenched in risk assessment. Accordingly, we need to focus on the development of evaluation techniques of ecological risk. Conventional techniques for hazard assessment may not be able to fully evaluate the effects of nanomaterials on human health and ecosystems. To address these issues, we started a research program on innovation in the evaluation and management of chemical substances. This program consists of three projects, namely studies of risk for ecosystems, nanomaterial toxicology and management strategies for the risks posed by numerous chemical substances.

1. Research into methodologies for ecological risk assessment and management of chemical substances

We have been investigating ways of estimating the adverse effects of chemical substances on ecosystems in terms of their potential to make populations of living organisms extinct or to degrade ecosystem function. For this purpose, we made a tri-trophic (three-species) biotic community model that used the algae–zooplankton–fish system. We called this the three-species ecological risk assessment model (3SP-ERA model). The model included the temporal dynamics of chemical exposure to each species, interspecific interaction between adjacent trophic levels (prey–predator interaction), the kinetics of the toxicant (i.e. bioaccumulation) in the fish's body, dose-response function for several endpoints, and the age structure of the fish stocks. These comprehensive properties of the

model permitted us to integrate ecotoxicological data independently estimated from the three species with chemical information on bioaccumulation or bioconcentration factors and ecological information on the life history or phenological schedule of growth and reproduction of the target species in the field (Fig. 1).

Fig. 1 Basic structure of the three-species ecological risk assessment model. The model consists of three dynamic components, each of which represents one of the three trophic levels: algae, zooplankton, and fish. The prey–predator interaction between adjacent trophic levels follows the standard ecological modeling method. For the fish population there are three sub-models; they simulate the chemical's dynamics in the fish body, the adverse effects of the chemical on energy efficiency and energy allocation, and the dose–response function, which takes into account between-individual variability in sensitivity.

Population Growth Rate λ

Fish biomass M (t: time, a: age)

Survival:
$$M(a+1, t+1) = S_M(a)M(a,t)$$

Reproduction:
$$M(1, t+1) = F\left\{c + (1-c)\frac{D(t)}{h_d + D(t)}\right\}\sum_{a=100}^{420} M(a,t)$$

Zooplankton biomass D
$$D(t+1) = S_D D(t) - \frac{P_{max}\sum_{a=100}^{420}M(a,t)}{h_d + D(t)}D(t) + \gamma G_{max}\frac{A(t)}{h_a + A(t)}D(t)$$

Algae A Growth
$$A(t+1) = \lambda e^{-\frac{ln\lambda}{K}A(t)}A(t) - G_{max}\frac{D(t)}{h_a + A(t)}A(t)$$

Fish(Medaka)

Pollutant chemicals

Bio-accumulation model
$$C^*(t+1) = k_E x(t) + (1 - k_E)C^*(t)$$

DEBtox Model
$$L(t+1) = L(t) + \max\left[\frac{\gamma}{1-h(t)}\{L_{max}(1-h(t)) - L(t)\}, 0\right]$$

Daphnia

Pollutant chemicals

Toxico-kinetic Toxico-dynamic model
$$h_z(t) = \eta\min\left[1, \max[0, C^*(t) - z]\right]$$

Algae

Pollutant chemicals

Furthermore, we have developed an analytical method for capturing the ecological risks posed by chemical substances with complex modes of action, such as endocrine disruptors. An extended reproduction test using *Daphnia magna* has been proposed for quantifying the effect of endocrine disruption in terms of sex ratio distortion as a new endpoint. To compare the ecological risks from endocrine disruptors with those from other chemicals, we developed a mechanistic model that evaluated the effect of the chemical on sex expression and fecundity at a population level. We also developed a new statistical method, based on MCMC (Markov Chain Monte Carlo) simulation, which estimates model parameters by using an extended reproduction test.

There are a number of uncertainties in deciding on environmental benchmarks for chemical pollutants to regulate pollutant release levels. Such uncertainties may result from errors in estimating the environmental exposure concentrations, the sensitivity of the organisms to the pollutants, and the costs of reducing pollutant discharges. We attempted to present a theoretical framework that supported decision-making about the most reliable benchmark concentration or countermeasure; the framework was designed to guarantee that the benchmark exposure concentration was minimally affected by arbitrarily large uncertainties

arising in the process of estimating the ecological hazards to biodiversity. To achieve this goal, we used an analytical approach to operational research, namely information-gap decision theory. As a case study, we applied our approach to the regulation of zinc discharges from business facilities along the Kasukawa River (Gunma, Japan).

2. Development of a methodology for evaluating nanomaterials toxicity and research into nanomaterials safety

The second nanotoxicology project started this fiscal year. In the first project we used laboratory animals and mammalian cells to investigate the health effects of nanoparticles such as the ultrafine particles contained in diesel exhaust, carbon nanotubes, and heat-treated asbestos. The second project focuses on the mechanisms of toxicity of carbon nanotubes, the *in vitro* and *in vivo* toxicity of silver nanoparticles and dendrimers, and the use of embryo and sac-fry fish in the ecotoxicological evaluation of titanium dioxide (TiO_2) nanoparticles. In addition, an *in vitro* system of nanoparticle exposure at the air–liquid interface is to be developed for toxicity screening of nanomaterials in this second project.

In the carbon nanotube study, mice were exposed to 1.36 mg/m^3 multi-walled carbon nanotubes (MWCNTs) 2 h a day for 5 days inside inhalation facilities developed during the first project. The mice's lung tissues were examined histopathologically and biochemically 24 h, 7 days, and 1 month after exposure ended. Their alveolar macrophages were found to contain MWCNTs, and levels of angiotensin-converting enzyme and endothelin-1 mRNAs in the lung tissues were increased. However, inflammation with neutrophil infiltration and epithelial hyperplasia—benchmarks of acute lung injury—was not observed in the MWCNT-exposed mice (Fig. 2).

Fig. 2
Photomicrographs of lung tissues obtained from control mice and mice exposed to multi-walled carbon nanotubes (MWCNTs). Arrows indicate alveolar macrophages containing MWCNTs.
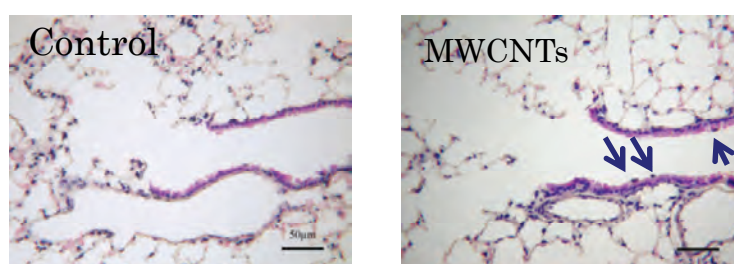
In the silver nanoparticle study, we used mammalian cells such as BEAS-2B bronchial epithelial cells and J774 macrophages to evaluate the cytotoxicity of silver nanoparticles and silver ions. The physicochemical characteristics of silver nanoparticles in culture medium were measured by using dynamic light scattering and electron microscopy. Silver ions induced the production of metallothioneins quickly and transiently, and the production of cytosolic metallothioneins led to the generation of reactive oxygen species in the mitochondria. Silver nanoparticles were not as effective as silver ions in inducing metallothionein

production. PAMAM (polyamidoamine) dendrimers were labeled with an Alexa Fluor® fluorescence tag to investigate the behavior of polymer-based nanoparticles. A toxicokinetics and toxicodynamics *in vivo* study using these fluorescence-tagged dendrimers is now under way. For effective exposure of mammalian cells to nanoparticles *in vitro*, we have been using the Cultex® system, with some modifications. We have aerodynamically simulated the deposition of nanoparticles at the air–liquid interface of cultured cells to estimate the amounts of nanoparticles on the cell monolayers.

TiO$_2$ nanoparticles have been widely used in construction materials and cosmetics and are presumably released into the environment. We exposed fish embryos to TiO$_2$ nanoparticles at a concentration of 25 mg/mL with or without ultraviolet irradiation (11.8 W/m^2) and assessed the effects of the exposure by viability evaluation. Exposure to TiO$_2$ nanoparticles alone did not change viability, whereas co-exposure to TiO$_2$ and UV light significantly decreased viability, suggesting that UV-irradiation of TiO$_2$ nanoparticles generates secondary toxic substances such as reactive oxygen species.

Our goal is to establish a health-risk assessment framework and to help to formulate international guidelines for safety evaluation of nanomaterials. To this end, more sophisticated testing methods need to be developed, focusing on the shape, dispersibility, and surface charge of nanomaterials.

3. Research into strategic approaches to managing the risks posed by chemical substances

Numerous chemical substances have different effects and characteristics. In this project, we intend to investigate 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 will focus on developing a model for predicting spatiotemporal changes in agricultural chemicals. Assessment methods that consider temporal variations in emissions and risks to the aquatic environment will be studied as major examples of the theme; PeCHREM/G-CIEMS (Pesticide Chemicals High Resolution Estimation Method/Grid-Catchment Integrated Modeling System) models will be used. Sub-theme 1-2 will focus 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 first targets of the study. Sub-theme 1-3 will focus on developing a global multimedia model (the Finely-Advanced Transboundary Environmental model, or FATE) for predicting the fate of persistent organic pollutants. We will explore the development of an assessment methodology based on the global distribution. Theme 2 will focus on strategies for managing the different dimensions of risk posed by various chemical substances in society. A variety of characteristics of risks from chemicals will be considered in various social contexts in terms of spatiotemporal variation, substance life cycle, the uncertainties of scientific

knowledge, and the varied nature of the impacts and social receptivity. We will then organize the results of these research activities and propose a methodology and ideas for efficiently evaluating and managing the risks posed by chemical substances.

In FY 2011, we studied refinement of the PeCHREM model on the basis of new results from a field survey under sub-theme 1-1. We also explored the validation of the FATE model by using monitoring data on polychlorinated biphenyl (PCB) congeners under sub-theme 1-3. Figure 3 shows the validation results for the PeCHREM/G-CIEMS and FATE models for herbicides and PCB congeners. Under sub-theme 1-2, we also explored the emission of PBDEs (brominated flame retardants) and PFOS (a fluorinated chemical) from some household products to air and water. Furthermore, we started literature-based discussions to set the direction of study in theme (2); we discussed the various social contexts of risk assessment and the management of risk issues.

Fig. 3
(a) Relationships between predicted concentrations which were calculated by the PeCHREM/G-CIEMS model and observed ones of 18 high-accuracy herbicides (HH) and seven low-accuracy herbicides (LH) at seven river sites. The values were categorized on the basis of the average absolute values of logarithmic difference.
(b) Inter-seasonal variabilities of the FATE-predicted (model) and observed (obs.) atmospheric concentrations of selected PCB congeners.
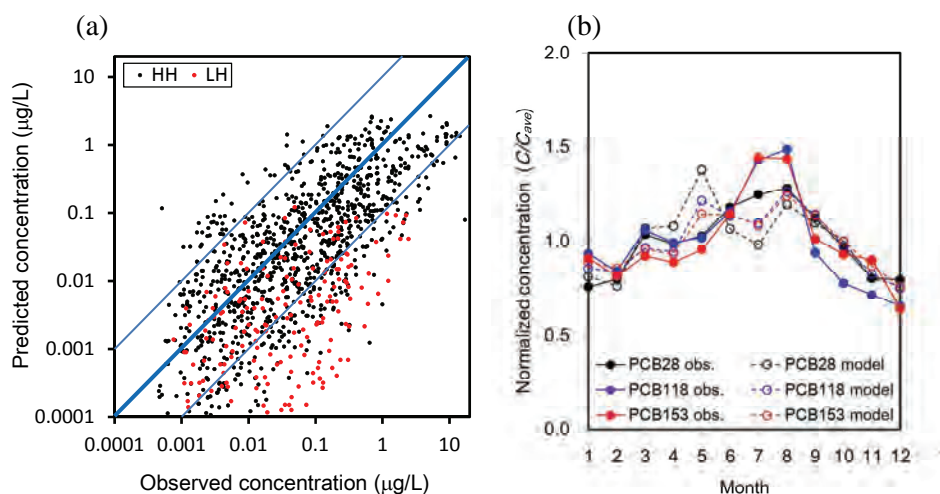
Fundamental research to support environmental action plans
To minimize the risks posed by chemical substances we have been running research projects to develop a comprehensive view of risks to human health and ecosystems. We have also been developing techniques for assessing and managing these risks on the basis of transparent and scientific evidence, with an emphasis on a preventive approach. We need to propose techniques for addressing such issues in the real world and for using these techniques. For this purpose, we intend to perform research aimed at providing tools for predicting chemical toxicities and evaluating the adverse effects of complex mixtures of chemicals in the environment. The theme will be "research into the risk assessment of chemical substances in line with environmental action plans."

(1) Development of a new method for estimating emissions of chemical substances to the environment

We intend 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 in the past. Such factors include emissions from various processes (e.g. the manufacture and use of chemical substances and the exposure of humans and living organisms), as well as the changes in these emissions over time. In FY 2011 we compiled information on existing methods and tools. Figure 4 illustrates the considerable difference between the emission factors used in the framework of Japan's CSCL (Chemical Substances Control Law) and in EU-TGD (the European Union's Technical Guidance Document); this difference may need to be discussed in more detail in the next step of our research.

Fig. 4 Emission factor comparison between the framework of Japan's Chemical Substances Control Law (CSCL) (a, c) and the European Union's Technical Guidance Document (EU-TGD) (b, d). Maximum and minimum emission factors to atmosphere (a, b) or to effluent water (c, d) are shown in association with use categories.
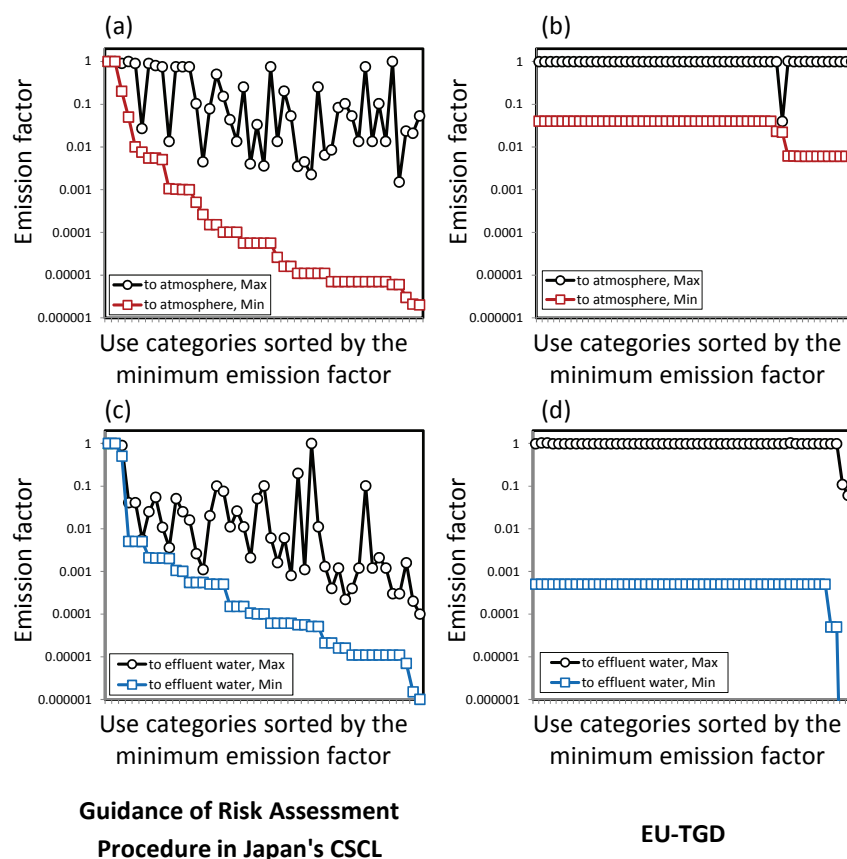
(2) Research into development and use of a method for predicting the toxicity of chemicals

In June 2007, a new chemicals regulation on the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) was implemented by the European Union. Moreover, in Japan, the CSCLs (or *Kashinhou*) were amended to introduce a comprehensive system for the control of chemicals. Under these requirements for the assessment of new and existing chemicals, (quantitative)

structure–activity relationship [(Q)SAR] models have been used so as to conform with the regulatory purposes in countries within the OECD (Organization for Economic Co-operation and Development).

We developed the KATE (*KAshinhou* Tool for Ecotoxicity) system, which has ecotoxicity QSAR models for fish and daphnia acute toxicity, and we investigated the efficiency of additional domains for the models. Then, using Gasteiger's PEOE (partial equalization of orbital electronegativity) method, we constructed ecotoxicity-prediction QSARs based on two-dimensional descriptors for acrylic acids and compounds with acrylate-like substructures (Figs. 5 and 6).

Fig. 5
Left: acrylic acids.
Right: compounds with acrylate-like substructures
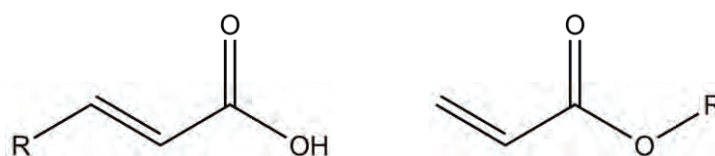
Fig. 6 Correlation between measured and calculated fish (upper; F models) and daphnia (lower; D models) toxicities of acrylic acids and compounds with acrylate-like substructures. The F-II and D-I models had the lowest AIC (Akaike information criterion) for fish or daphnia toxicity. This suggested that model F-II for fish toxicity and model D-1 for daphnia toxicity were the best models for the dataset.
log P_{OW}: the log of the octanol/water partition coefficient
$L(E)C_{50}$: 50% lethal (effective) concentrations
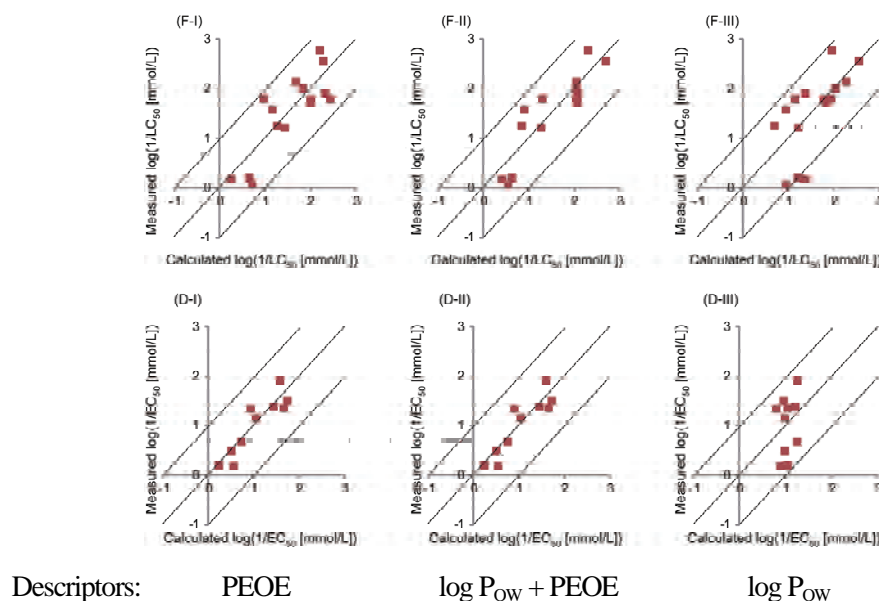
Furuhama A. et al.,
SAR QSAR Environ. Res., in press.

We also developed two approaches to extrapolate chronic ecotoxicity from acute ecotoxicity data. The first approach uses regression models and provides a reasonable statistical background for predicting chronic ecotoxicity from the correlative relationship among ecotoxicity data. The second approach applies a simple Bayesian framework to predict the posterior probability that the chronic toxicity exceeds a threshold value for screening chemicals. From the acute ecotoxicity of the chemicals, this approach estimates the false-negative rate for chemicals during the screening process.

(3) Development of biological testing techniques based on mechanisms of action of chemicals

Human health and ecosystems are likely affected by combined exposure to the various environmental chemicals in the environment, including to 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. Good tools for evaluating combined exposure to multiple chemical substances are *in vivo* or *in vitro* bioassays, by which chemical substances are classified on the basis of their mechanisms of action. The following research projects are focused on evaluating the hazards of multiple chemical substances in the ambient air and aquatic environment:

i. Anatomization of the mutagenic or carcinogenic potency of environmental chemicals. By using an *in vivo* and *in vitro* bioassay system such as bacterial mutation testing and transgenic rodent testing, we intend to analyze how polycyclic aromatic hydrocarbons (PAHs), nitrated PAHs, and other identified chemicals contribute to the total mutagenicity or carcinogenicity of chemicals contained in the particulate matter in ambient air. We also plan to use bioassay systems to identify the major components inducing mutagenicity and carcinogenicity.

ii. Analysis of the endocrine-disrupting activities of chemical substances. By using a yeast two-hybrid bioassay system, we have subjected various chemicals detected mainly in aquatic environments to screening for ligand-dependent transcriptional activity. Already, about 600 chemicals have been screened; 30% and 46% of the screened chemicals have shown agonist activity toward the aryl hydrocarbon receptor and the constitutive androstane receptor, respectively. Data from the screening will be published in our database.

Center for Regional Environmental Research
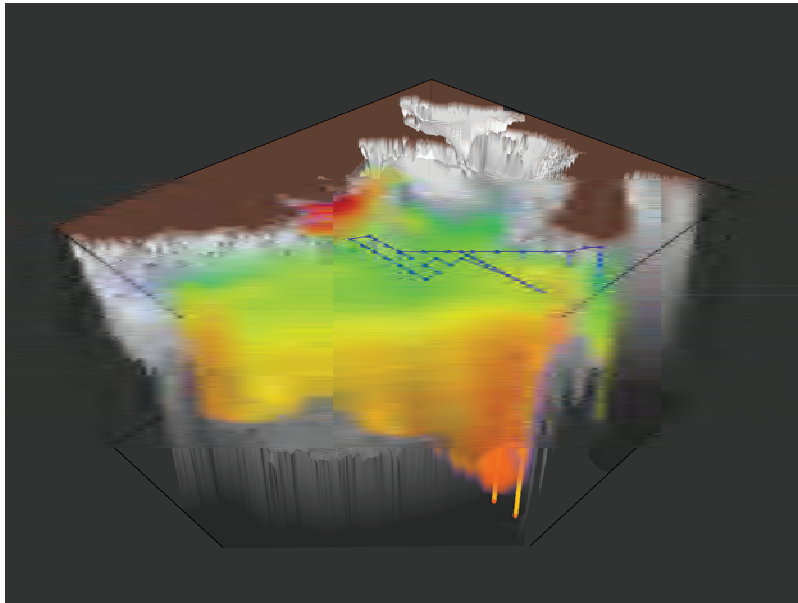
Nitrate concentrations in the East China Sea in June 2010. Observed and simulated data are overlaid. The Changjiang River is a major nitrate source for surface waters in the East China Sea.

Nitrate observation in the East China Sea using a CTD (conductivity, temperature, and depth system) equipped with a vertical nitrate profiler.

I. Outline of the Center for Regional Environmental Research

The environmental impacts of human activities influence both humans and ecosystems through the atmosphere, water, and soil. To provide a scientific basis for minimizing these environmental impacts, the Center for Regional Environmental Research is investigating at multiple scales (local, urban, and trans-boundary) the mechanisms by which regional environmental issues develop in Asia and Japan. In addition, we are studying solutions for regional environmental issues and their application to the real world.

The Center consists of seven sections (the Regional Atmospheric Modeling Section, the Regional Atmospheric Environment Section, the Urban Atmospheric Environment Section, the Water Quality Management Section, the Lake and River Environment Section, the Marine Environment Section, the Soil Environment Section, and the Regional Environmental Systems Section) and has two special senior researchers.

In FY 2011, we implemented many research projects covering a wide range of regional environmental issues. Our main research projects were: one Priority Research Program (the East Asian Environment Research Program); two advanced research programs (the Basin Ecosystem Functions Research Program and the Eco-city Systems Research Program); a cross-discipline research project (Coordinated Study of Environmental Emissions and Behavior and Effect of Metals in High-tech Products, Focusing on their Lifecycles); and five special research projects (Development of a Co-benefit Treatment System for Liquid Waste Derived from Crop Resources, Deterioration of Sedimentary Environments and Assessment of its Impacts on Benthic Fauna in Coastal Seas close to Urbanized Areas, Environmental Behavior and Toxicity of Secondary Organic Aerosols, Cycling of Organic Matter and its Interaction with Microbial Ecosystems in Lakes, and Evaluation and Prediction of Nitrogen Loads from Nitrogen-saturated Forest Areas and Development of a Scenario for their Reduction). Of particular interest were research projects concerning multimedia modeling and long-term monitoring of radioactive substances emitted from the Fukushima Daiichi Nuclear Power Plant. Most of the projects are collaborations with other centers at NIES. At our Center, there are two long-term monitoring programs: the Regional Atmospheric Monitoring Program and the GEMS (Global Environment Monitoring System)/Water Program, which is a collaboration with the Center for Environmental Biology and Ecosystem Studies.

We give brief accounts of some of the important results from the Center's research in 2011.

II. Research Programs

East Asian Environment Program

Japan is closely connected to Asia both geographically and economically, and rapid development is expected in Asia in the future. Therefore, as part of East Asia, Japan needs to help preserve the East Asian environment in order to promote environmental security and a sustainable society throughout the whole of

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 trans-boundary 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 overall program will help to solve wide-scale environmental issues in East Asia.

Project 1: Analysis and evaluation of multi-scale air pollution by integration of observation and modeling

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

The *Ozone Monitoring Team* has examined springtime ozone trends at nine remote locations on the East Asian Pacific rim during the last decade (1998–2006) (Fig. 1). The observed decadal ozone trends are relatively small at surface sites but are substantially larger at mountainous sites. Both the levels of ozone and their rates of increase at mountainous sites are higher than those observed at background sites in Europe and North America. We use a regional chemistry-transport model to explore the observed changes and how changes in Asian anthropogenic emissions have contributed to these increasing trends. The model, which shows year-dependent regional emissions, successfully reproduces the levels of ozone, as well as their variability and interannual variations, at all the surface sites. It predicts increasing trends at the mountainous site and suggests that increasing Asian anthropogenic emissions account for about half of the observed increase. However, there is a discrepancy between the observed and modeled results after 2003 (the time of the greatest emission increase); this suggests that the model substantially underestimates the actual growth of Asian anthropogenic emissions, or that the modeling of pollution exported from continental Asia is incomplete.

Fig. 1 Daily (24-h) mean ambient mixing ratios of ozone observed at Mt. Happo (dots) for the period 1998 to 2006. Also shown are the trend component (solid line) of the best-fit curve for daily means and its uncertainty range (gray region) since 1999.

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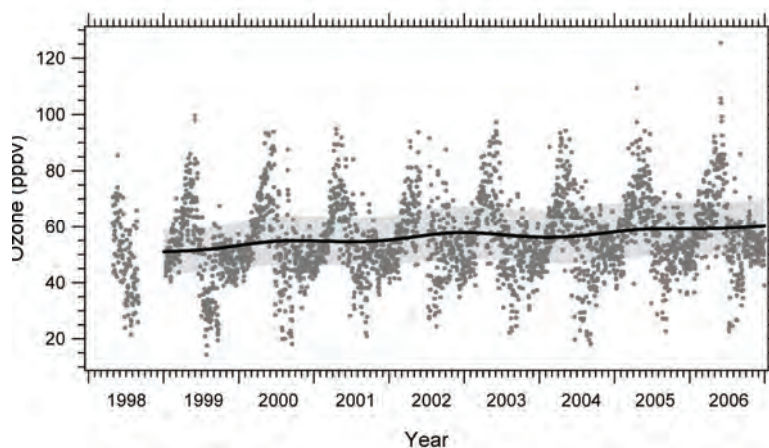
The Aerosol Measurement Team has set up an aerodyne aerosol mass spectrometer (Q-AMS) in the city of Fukuoka, one of the biggest cities in western Japan, to monitor aerosols produced within the city and distinguish them from those transported long distances from the Asian continent. According to the Q-AMS measurements, the aerosols above Fukuoka are mainly sulfates, organics, and nitrates. Sulfates and organics have been observed during almost all the monitoring periods, whereas nitrates and chlorides have been observed only periodically. Back-trajectory analysis suggests that air masses are transported from the Asian continent during the sulfate-rich period and within a distance of about 50 km during the nitrate-rich period. Both aerosols of local origin and those transported long distances have been observed at the same time.

The Modeling Team examined the future development of tropospheric ozone over East Asia by using representative concentration pathway (RCP) scenarios. For this, future projections of tropospheric ozone under RCP scenarios generated by a global chemistry climate model (CCM) were further downscaled by using a regional chemistry transport model (CTM) to focus on the East Asian region. The projected future surface-ozone concentration in 2050 would decrease from the present (2005) level over most of the East Asian region under the RCP 2.6 and 4.5 scenarios (Fig. 2). Both scenarios assume reductions in the emission of ozone precursors (NO_x and non-methane hydrocarbons: NMHCs) in East Asia; these reductions are the main determinants of the decrease in surface ozone levels in the region. In contrast, a general increase in surface ozone levels was calculated under the RCP 8.5 scenario. This scenario also assumes a reduction in ozone precursor emissions over wide areas of East Asia, but unlike in the other RCP scenarios, the reduction is not sufficient to achieve a reduction in surface ozone levels over the whole East Asian region. The increase in surface ozone over East Asia under the RCP 8.5 scenario is largely influenced by future climate change. A reduction in cloud cover and the resulting increase in solar radiation in the future climate of East Asia under the RCP 8.5 scenario is one possible cause of the ozone increase under this scenario. Although highly elevated ozone concentrations occur only rarely under each RCP scenario, the frequency distribution (FD) of 1-h surface ozone in the megacities of East Asia differs greatly among the scenarios. The mode of the FD does not change greatly in RCPs 2.6 and 4.5, but it increases by about 10 to 15 ppbv in RCP 8.5. We also intend to demonstrate differences between the global CCM and the regional CTM in the future projections of surface ozone.

Fig. 2 Annual mean surface O_3 changes (2050–2005) for RCPs 2.6 (left), 4.5 (center), and 8.5 (right). Shading denotes statistically insignificant change at the 1% level.
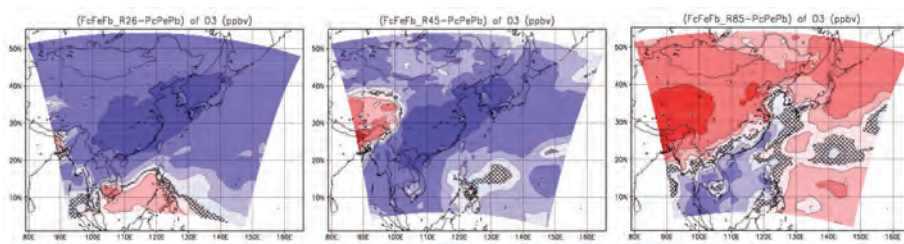
Project 2: Study of wide-scale anthropogenic impacts on marine ecosystems in the East China Sea and the seas around Japan

There is concern that increasing anthropogenic pollutant loads from terrestrial East Asia may cause wide-scale degradation of marine environments, as exemplified by the occurrences of red tides on the continental shelf of the East China Sea (ECS). This project aims to develop integrated numerical models that can simulate the impact of human activity in China's Changjiang River basin on the environment in the ECS and the seas around Japan. For this purpose, we intend to: (1) estimate natural and anthropogenic emissions of nitrogen (N) and phosphorus (P) in the basin and their discharges to the marine environment, and (2) clarify the mechanisms of transport of these emissions to the continental shelf of the ECS and their impact on marine ecosystems. We made the following progress in our research in 2011.

To quantify total N and P loads in the basin, we took a system that we had developed to evaluate water and material cycles in catchment ecosystems and that had been well validated in our previous study in the Hanjiang River basin (a subcatchment of the Changjiang) and applied it to the entire Changjiang basin on a trial basis. We calculated the total COD (chemical oxygen demand) and N and P emissions per unit of industrial and human activity in the delta area by using a water inventory based on an input–output analysis model (Fig. 3). These preliminary studies showed that the total emissions of N and P in the delta area were close to the total inflows of N and P from all of the upstream parts of the Changjiang River to the delta. This implies that human activities in the delta area, which is the engine for economic development in the entire basin, are likely having a marked effect on the marine environment.

Fig. 3 Total nitrogen (T-N) and phosphorous (T-P) discharges in the delta of the Changjiang River, China, in 2000, listed by sector.
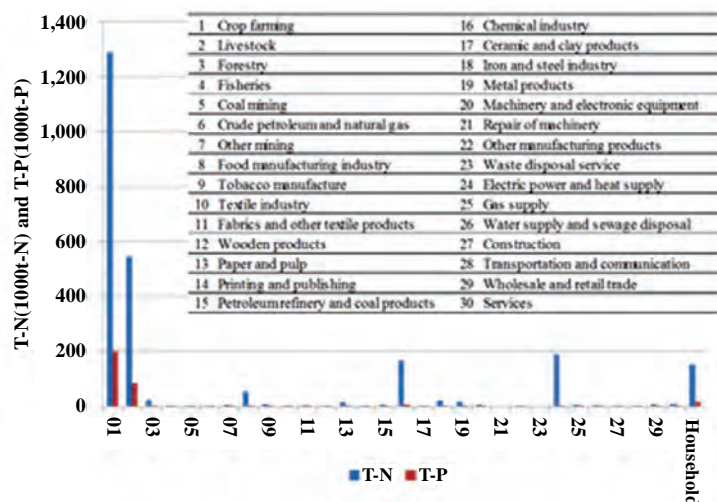
To assess anthropogenic impacts on the marine ecosystem in the ECS, we focused on the ecological dynamics of the dinoflagellate *Prorocentrum dentatum*, which we used as an indicator of environmental degradation. We performed a large-scale incubation test of *P. dentatum* in the laboratory, and we measured the vertical profiles of seawater temperature, salinity, microturbulence, and nitrate to clarify the factors affecting the occurrence of *P. dentatum* in the ECS. These studies

indicated that *P. dentatum* is capable of diurnal vertical migration (Fig. 4) and probably uses available nutrients below the pycnoclines in the ECS. The studies were also useful in improving the reproducibility of our biogeochemical model of the ECS. Our model tentatively shows that the presence of *P. dentatum* on the continental shelf is induced both by horizontal transport of this dinoflagellate from the Changjiang estuary in the surface and subsurface water layers and by horizontal and upward diffusion of its nutrient supply in the middle and bottom waters. These movements depend strongly on the Taiwan Warm Current, the degree of dilution of marine waters by the water from the Changjiang, and the monsoon winds in spring and early summer.

Fig. 4 Diurnal vertical migration of the dinoflagellate *Prorocentrum dentatum* in a large-scale tank. (Contours show the ratios of chlorophyll fluorescence intensity relative to the vertically integrated intensities.) L, light; D, dark
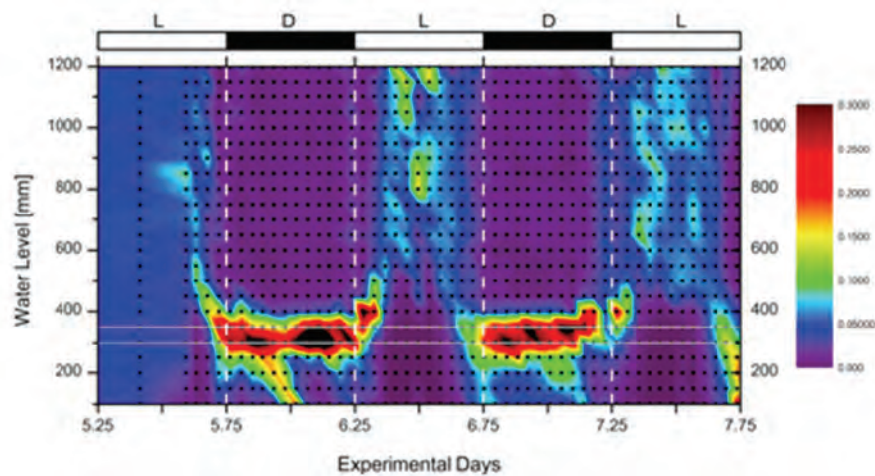
Basin Ecosystem Functions Research Program

To develop methodologies for the quantitative assessment of ecosystem function, we are focusing on material and water cycles for basin ecosystems (e.g. forests, lakes and wetlands, rivers, and coastal regions). We are also performing long-term strategic monitorings and assessing the relationships between ecosystem function and various environmental factors. On the basis of these assessments, we intend to develop methodologies and techniques for evaluating the health of basin ecosystems. Eventually we intend to determine the optimum conditions for the restoration and conservation of ecosystems.

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

We have started an investigation of nitrogen dynamics within a conifer plantation that is being thinned at different intensities—unthinned, weakly thinned, and intensively thinned—under a mildly polluted atmospheric environment. Our results to date clearly show the effect of thinning intensity on soil nitrogen dynamics (Fig. 5). The vertical profiles of nitrate concentration in the soil water differed substantially among the three treatments. The nitrate concentration in the surface A layer at intensively thinned sites was much lower than those at the other treatment sites. This suggests that there is an aboveground–belowground linkage in the conifer plantation ecosystem whereby development of the herbaceous soil

layer was induced by intensive thinning.

We have developed a rapid real-time method for quantifying phytoplankton primary production by using an active fluorescence technique, fast repetition rate fluorometry (FRRF), without the need for radiocarbon. We applied this new method at Lake Kasumigaura, and contrary to our expectations, we found that primary production was low in an area where a massive cyanobacterial water bloom had occurred. We also investigated the long-term dynamics of the bloom-causing cyanobacterium *Microcystis aeruginosa* in Lake Kasumigaura by quantifying its 16S rRNA gene in frozen samples using real-time polymerase chain reaction. We found that *M. aeruginosa* was present in the lake throughout the year, and that its density has been rising substantially since 2004.

To quantify the effects of the green tides formed by *Ulva* species on ecosystem functions on tidal flats, we selected two sites in Chiba Prefecture, Japan: the Yatsu tidal lagoon, where green tides are present year-round, and the Sanbanze tidal flat as a control. By applying a newly developed molecular identification method, we found that the composition of *Ulva* species differed between the two sites, and that this difference probably led to differences in the composition of other species inhabiting the flats. Moreover, we clearly observed the effect of green tide formation on the sediment environment. The nutrient concentration of interstitial water and the values of parameters related to the growth and decay of *Ulva* species differed markedly between the tidal flats.

Fig. 5 Observed vertical profiles of nitrate nitrogen concentration in soil water at conifer plantation sites with different thinning intensities: unthinned, weakly thinned, and intensively thinned.
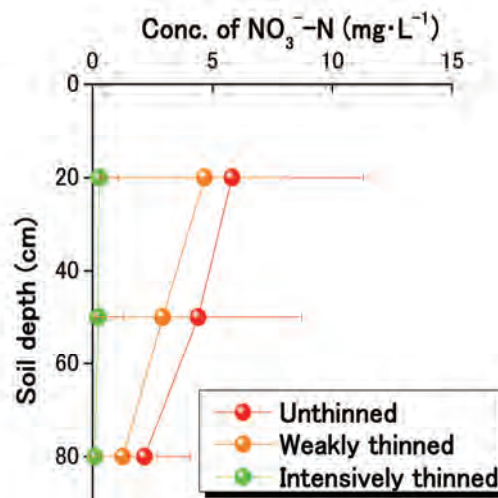
Project 2: Development of a strategic environmental assessment technology and its application to watershed restoration

This year, we launched the environmental monitoring of dam reservoirs and a natural lake in collaboration with Ubon Ratchathani University (Thailand), the Department of Fisheries (Thailand), and Battambang University (Cambodia). In this monitoring, we are measuring primary productivity by using a ^{13}C method and the densities of toxic algae by using real-time PCR. We are also measuring the enzymatic activity of soil bacteria (especially phosphatase activity as a surrogate of phosphorus cycling rate), in addition to other fundamental water

quality attributes such as pH, dissolved oxygen, and water temperature.

The objective of measuring primary productivity and enzymatic activity is to determine whether or not man-made water bodies such as reservoirs can be rich enough in nutrients and sustain sufficient fish production from aquaculture to compensate for the loss of capture fisheries due to the blockage of fish migration by dam construction in the Mekong River. Fisheries, upon which the food security of millions of people living in the Mekong region is highly dependent, are supported primarily by long-distance migratory fish species. However, the industry, and hence food security, is severely threatened by plans to build at least 11 dams on the main stream, in addition to dozens on its tributaries.

Toxic algae such as *M. aeruginosa* (cyanobacteria) may develop blooms in reservoirs, causing deterioration of water quality and massive die-offs of freshwater fish. From our real-time PCR studies, we detected *M. aeruginosa* in two out of three reservoirs we sampled in Thailand, albeit at relatively low concentrations (Fig. 6). The algae were observed commonly in Tonle Sap Lake, the largest freshwater lake in South East Asia. The number of reservoirs monitored will increase over the course of the project, allowing us to predict the risks of the algal blooms at newly constructed reservoirs through statistical and GIS analyses of observed algal densities and basin-wide environmental data, including those for land cover and the distribution of human populations.

Besides monitoring the reservoirs, we investigated the migration history of a cyprinid fish by using otolith microchemistry. We also conducted a field survey in northern Vietnam to find candidate sites for mangrove restoration among abandoned shrimp farms. Next year, we will intend to use remote sensing to systematically search the coastal areas of Vietnam for suitable restoration sites.

Fig. 6 Concentrations of *Microcystis aeruginosa* measured by real-time PCR in three reservoirs in Thailand and three locations (A, B, and C) in Tonle Sap Lake, Cambodia. Error bars represent ±1 SE. Red horizontal line in the graph indicates the average concentration of algae during 1999–2011 in Lake Kasumigaura, Japan. Blue horizontal line indicates the detection limit.
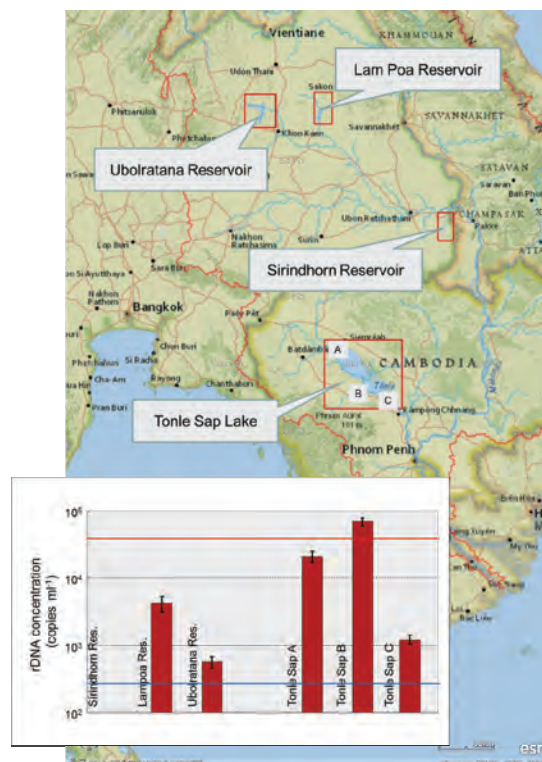
III. Special Research

Environmental Behavior and Toxicity of Secondary Organic Aerosols (FY 2009–2011)

Introduction. Secondary organic aerosol (SOA) is formed by the photochemical reaction of volatile organic compounds (VOCs) in the atmosphere. SOA is one of the major components of fine particles observed in the air in both urban and remote areas. Because SOA is formed from oxidation processes, it is thought to contain oxidants and therefore may have adverse effects on human health. From 2009 to 2011, we conducted a special study on Environmental Behavior and Toxicity of Secondary Organic Aerosols so as to better understand SOA behavior and toxicity. SOA was produced under controlled conditions and the oxidative stress that it caused was examined by exposing cells to off-line SOA sample extracts.

Method. SOA is produced by the atmospheric oxidation of various kinds of VOCs. Some are anthropogenic and others are biogenic. *m*-xylene and α-pinene were selected as representative of anthropogenic and biogenic VOCs, respectively. SOA from α-pinene (hereafter; α-SOA) was prepared by its ozonolysis in a Teflon bag. The reaction occurred immediately, and particulate matter (PM) was formed; this was confirmed with a scanning mobility particle sizer. PM was collected on the Teflon membrane filter and the chemical species present in the filter sample extract were analyzed by using gas or liquid chromatography–mass spectrometry. The total amount of oxidant present in the PM was determined by iodometric spectrophotometry (KI method). SOA from *m*-xylene (x-SOA) was prepared by irradiating the gaseous *m*-xylene–NO_x–air mixture in the Tedlar bag with UV from black lights. In summer 2011, ambient $PM_{2.0}$ aerosols were collected, using high-volume samplers, from Tsukuba in Ibaraki Prefecture (about 100 km northeast of central Tokyo) and Kisai in Saitama Prefecture (about 100 km north of central Tokyo). To evaluate the toxicity of SOA, water-soluble organic compounds of SOA were extracted with culture medium. Alveolar epithelial cells (SV40-T2) were cultured with various concentrations of the extracts. Cytotoxicity was evaluated by using WST-8, and oxidative stress response was examined by quantitative real-time RT-PCR for mRNA expression of heme oxygenase-1 (HO-1).

Results and discussion. The chemical analysis of α-SOA showed that the products were similar to those reported in the literature. This means that the SOA samples we obtained were very similar to those obtained using larger environmental chambers, and that our toxicity study was conducted under reproducible conditions.

Extracts from both α-SOA and x-SOA induced the expression of HO-1 mRNA (Fig. 7). The ratios of oxidative stress caused by α-SOA and x-SOA were about 10 and 250, respectively, with respect to the blank sample. The ratio caused by the ambient air samples from the two cities was about 2. This was small, but still quantifiable. These results indicate that SOA and ambient $PM_{2.0}$ aerosols induced oxidative stress in the cells. The oxidative stress–inducing capacity differed between the SOAs, which had been formed from different VOC precursors.

Fig. 7 Ratios of oxidative stresses caused by SOAs from various sources.
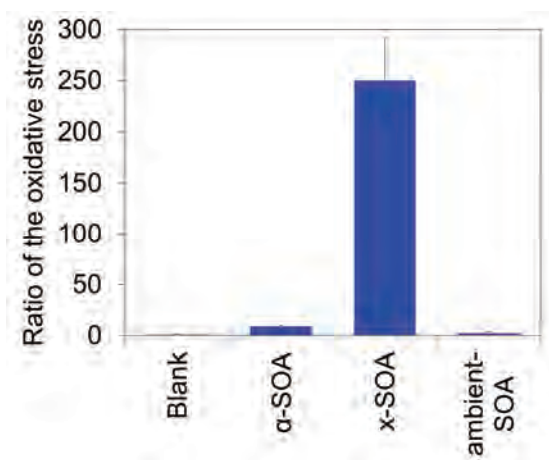
We also examined the relationship between oxidative stress and the total amount of oxidants per unit mass of PM (Fig. 8). Oxidative stress increased with increasing amount of oxidants. This result indicates that ambient SOA is an important inducer of oxidative stress, and that oxidants present in PM play an important role in this stress.

Fig. 8 Ratios of oxidative stress as a function of total amount of oxidants per unit mass of particulate matter (PM).
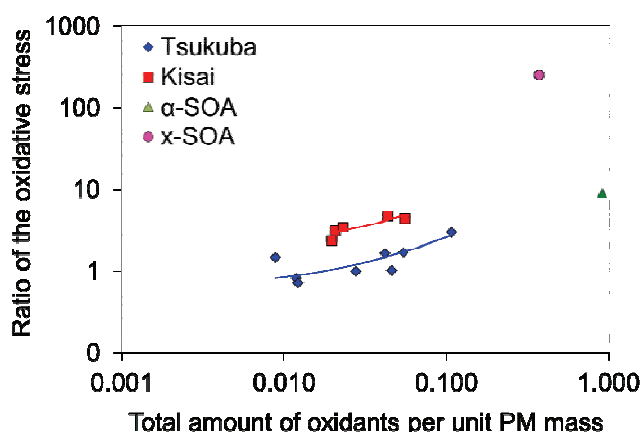
We also investigated the following subjects:

- development of a direct system of exposing target cells to SOA
- development of a system for measuring semivolatile species
- improvement of calculations in the SOA model
- revision of the inventory.

Summary. We successfully produced SOA from various VOC precursors by using ozonolysis in small bags. Oxidative stress differed among SOAs, which were formed from different VOC precursors. Ambient aerosols are also induced by oxidative stress.

The Biogeochemical Cycle of Organic Matter and its Interrelationships with the Microbial Community in Lacustrine Environments (FY 2008–2011)

In this study, we aimed to evaluate the interrelationships between the quantity and quality of dissolved organic matter (DOM) and microbial production (e.g. phytoplankton primary production and bacterial secondary production) in the shallow eutrophic Lake Kasumigaura. We also aimed to elucidate the mechanism of production of recalcitrant DOM through the use of long-term trend data and laboratory incubation experiments. Finally, by using lake-model calculations, we aimed to quantify the contributions of several allochthonous and autochthonous sources to lake recalcitrant DOM. Our latest findings are described below.

Elucidation of the mechanism of production of recalcitrant DOM in Lake Kasumigaura. We monitored heterotrophic bacterial growth, bacterial production, changes in concentrations of DOM as dissolved organic carbon (DOC), total dissolved amino acids (TDAA) and total dissolved neutral sugars (TDNS), as well as the chemical composition of TDAA and TDNS, during two incubation experiments using filtered water samples collected from the eutrophic Lake Kasumigaura. Bacterial production during the first few days was very high (20 to 35 μg C L^{-1} day^{-1}), and total bacterial production accounted for 30% to 50% of the decrease in DOC during the incubation experiments, indicating that bacterial activity in Lake Kasumigaura was high (Fig. 9A). D-amino acids, which are bacterial biomarkers, were used to estimate the bacterial contribution to the DOM pool in Lake Kasumigaura (Fig. 9B). Bacterially derived carbon accounted for 40% to 50% of the lake DOM. These values were much higher than those reproted in the open ocean (20% to 30%). This is the first study to estimate the bacterial contribution to a DOM pool in a freshwater environment. Our result indicates that bacteria play even more important roles in carbon and nitrogen cycles in freshwater environments than previously thought, and that recent increases in DOM (or recalcitrant DOM) levels in various lakes could result from high-level augmentation by bacterially derived carbon.

Dynamics of bloom-causing cyanobacterium *Microcystis aeruginosa* in the shallow eutrophic Lake Kasumigaura. We investigated which factors controlled blooms of *M. aeruginosa* in Lake Kasumigaura, a shallow eutrophic lake in the temperate zone of Japan, from 1999 to 2007 by quantifying the 16S rRNA gene of *M. aeruginosa* using real-time PCR. The results showed that *M. aeruginosa* was present in the lake water throughout the year. The abundance of *M. aeruginosa* usually increased from March to July and decreased from August to February. The factors determining the maximum density were the size of the overwintering population and the growth rate in summer. The overwintering population was affected by abundance during the previous summer. Growth rates of *M. aeruginosa* in summer were correlated significantly with the extinction coefficient and the mean daily photosynthetically active radiation (i.e. the irradiance). The mean daily irradiance in summer from 1999 to 2007 was 77% of that from 1983 to 1986, when blooms of *M. aeruginosa* occurred. Therefore, the most important factor controlling the growth of *M. aeruginosa* in Lake

Kasumigaura after 1999 appears to be the amount of light supplied to the water column.

Fig. 9 Incubation experiments on water from Lake Kasumigaura. (A) Bacterial secondary production during incubation experiments and (B) concentrations of D-aspartic acid (D-Asp), D-glutamic acid (D-Glu), D-serine (D-Ser), and D-alanine (D-Ala) during incubation experiments.
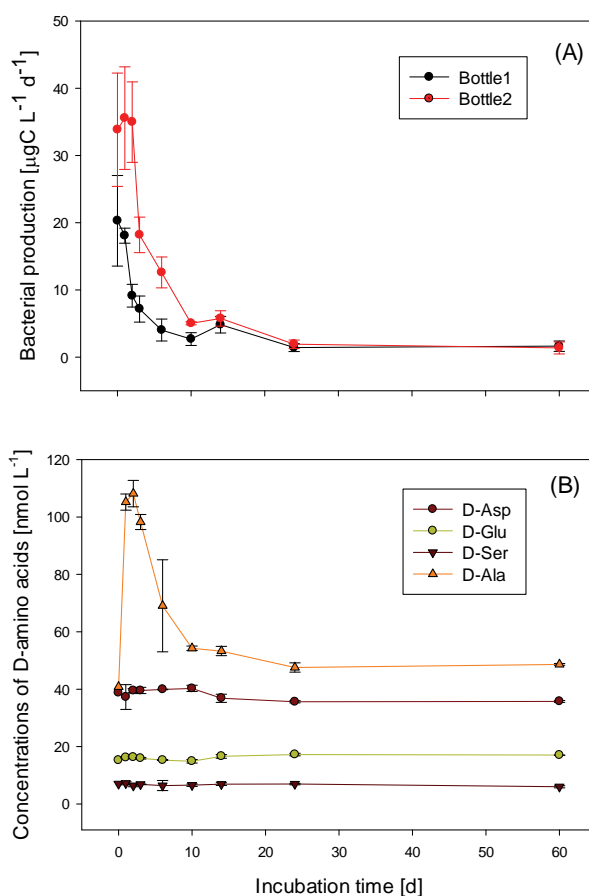
Direct evidence of nitrogen isotope discrimination and carbon isotope alteration in sediments during sedimentation and diagenesis in Lake Kasumigaura. We evaluated the degree of modification of N isotope composition during sedimentation and diagenesis by examining sediment core samples collected from Lake Kasumigaura from 1979 to 2007. We estimated the degree of isotope discrimination during diagenesis by comparing historical changes in the N isotope composition of the surface sediment (top 2 cm) against the vertical profile of the isotope composition of sediment core samples (15 cm depth). The degree of ^{15}N enrichment during sedimentation appeared to be substantial under the preferential N decomposition that occurred in periods when the suspended particulate organic matter had low C:N ratio values. We documented ^{15}N depletion in sediments deeper than about 3 cm during diagenesis. The contrasting directions of N isotope discrimination during sedimentation and diagenesis suggest that there were changes in the mechanisms of isotopic shift across an oxidation–reduction boundary.

We also examined the degree of apparent isotope discrimination by comparing long-term changes in the carbon isotope composition of the surface sediment (top 2 cm) with the isotope composition profile from 0 to 15 cm. The downcore C-isotope composition profile was close to the values calculated from the long-term changes in the isotope composition of the surface sediment, suggesting

that the sedimentary carbon isotope composition was generally conserved ($\pm$0.6‰) during early diagenesis (up to 30 years).

Development of a co-benefit treatment system for liquid waste (wastewater) derived from crop resources (FY 2009–2011)

Development of an appropriate treatment technology for molasses-based wastewater. Recently, bioethanol production from cane molasses has increased in South East Asian countries. Large amounts of concentrated organic wastewater are discharged during the distillation process, and the wastewater is normally left in stabilization ponds for a long time. This causes pollution of the aquatic environment and emission of greenhouse gases. One of the tasks of the **Regional Environmental Systems Section** is to develop appropriate wastewater treatment technologies.

Anaerobic treatment processes such as the use of an up-flow anaerobic sludge blanket (UASB) may be a suitable option because they can satisfy the need for both low operational energy and high organics-removal efficiency. However, the molasses wastewater contains large amounts of organic compounds and sulfate. These characteristics cause deterioration of the anaerobic digestion process through sulfide inhibition. In addition, high rates of treatment of molasses wastewater by UASB might cause sludge washout through vigorous biogas production. Therefore, we developed an anaerobic up-flow staged sludge bed (USSB) reactor equipped with multiple gas–solid separators as the main treatment and methane recovery system. A combination of an acidification reactor and a USSB reactor was used to treat molasses wastewater and investigate the performance of the system.

Figure 10 is a schematic diagram of the treatment system. The acidification reactor (volume, 13.7 L) and the USSB reactor (volume, 13.4 L) were continuously operated at 35 °C. The USSB had three gas–solid separators (GSSs) at various heights in the reactor to remove efficiently produced biogas. The hydraulic retention times of the acidification reactor and the USSB were 24.0 h and 23.7 h, respectively. The USSB recirculated effluent at nine times the volume of influent. The acidification reactor was started up without the need for seed sludge. The USSB was seeded with mesophilic granular sludge.

Fig. 10 Schematic diagram of the proposed treatment system for molasses-based wastewater.
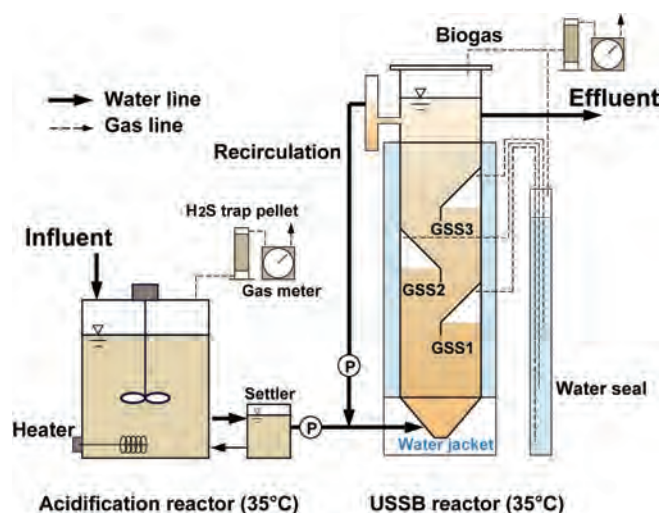
The organic loading rate of the USSB was increased stepwise by changing the influent COD concentration of the wastewater. The USSB gave high processing performance at a daily organic loading rate (OLR) of 43 kg COD/m^3 (Fig. 11A). The COD removal efficiency was 86.2% for total COD (Fig. 11B). This high process performance can be attributed to good retention of the sludge. The average concentration of sludge in the USSB was 40 g VSS (volatile suspended solids)/L, on the basis of the total volume of the reactor. The high COD removal rate of the USSB was caused by the high average methane gas production rate of 133 NL(normal liters)/day (380 g COD/day). The methane recovery rate based on the influent COD was about 70% in the USSB (Fig. 11B). The USSB achieved a high daily COD removal rate of 37 kg COD/m^3 (a COD removal efficiency of 86.2% at a daily OLR of 43 kg COD/m^3) in the treatment of molasses wastewater at 35 °C; this was higher than the results obtained in previous studies (in case use of UASB). This advantage should contribute to the development of compact reactor systems with a small carbon footprint and should give high energy yields in full-scale applications.

Fig. 11 Process performance of the proposed molasses-wastewater treatment system: (A) organic loading rate and COD removal rate(B) COD removal efficiency and methane recovery rate (based on influent COD).
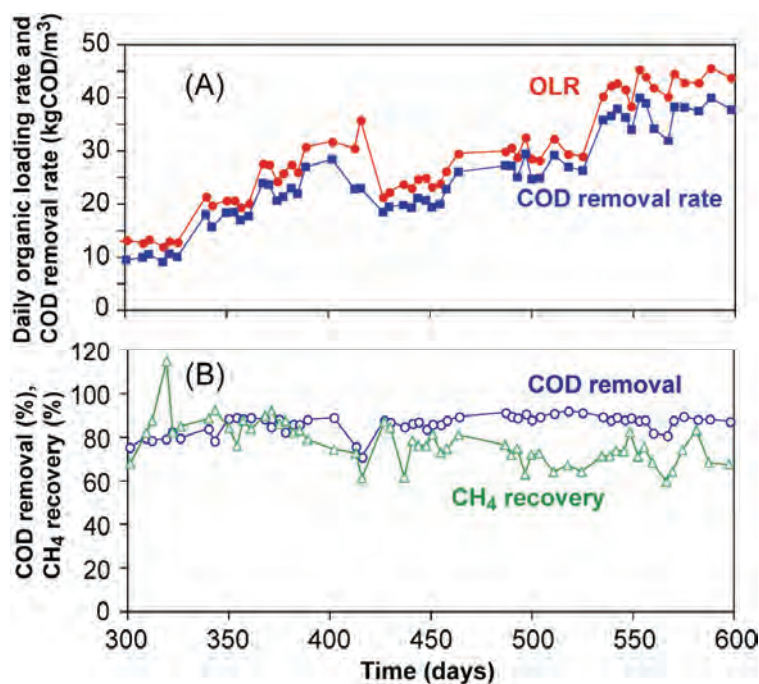
Molasses wastewater contains substantial amounts of sulfate. In anaerobic reactors this leads to the production of sulfide by sulfate-reducing bacteria. The sulfide suppresses the activity of methane-producing bacteria. We confirmed that there was a 20% level of inhibition of methanogenic activity at concentrations in the range of 200 to 350 mg S/L at pH 7.0 by batch examination.

Figure 12 shows the characteristics of sulfur removal in the treatment system. The influent sulfate concentration was about 500 mg S/L at an influent COD concentration of 42.4 g COD/L. (The daily OLR was 43 kg COD/m^3). The acidification reactor performed sulfate reduction followed by stripping of hydrogen sulfide from the wastewater. Although 150 mg S/L was reduced in the acidification

reactor, the remaining sulfate concentration was still high. Effective sulfide removal (237 mg S/L) was observed in the USSB. The amount of sulfide removed from each GSS was 70 mg S/L at GSS 1 (bottom portion), 80 mg S/L at GSS 2 (middle portion), 62 mg S/L at GSS 3 (upper portion), and 29 mg S/L at the top of the USSB. This result shows that the sulfide concentration in the sludge bed was effectively reduced by removal of hydrogen sulfide from the GSS. As a result, the sulfide concentration in the USSB effluent was kept at approximately 110 mg S/L. Thus sulfide inhibition could be suppressed even though the influent wastewater had high concentrations of sulfate. This feature is unique to the USSB.

Our results showed that the combination of the acidification reactor and USSB reactor is an attractive system for treating molasses wastewater.

Fig. 12
Characteristic of sulfur removal in the treatment system.
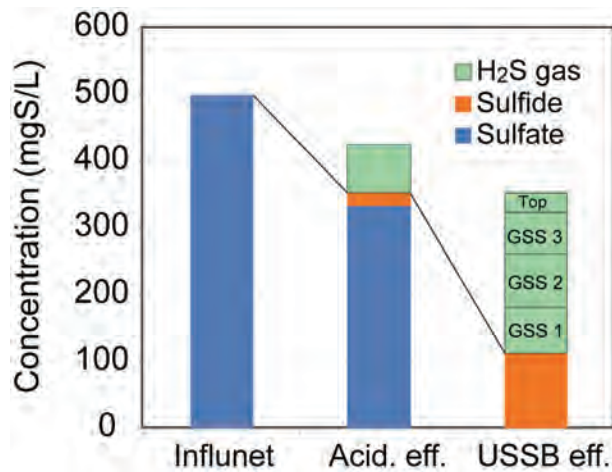
Center for Environmental Biology and Ecosystem Studies

Field work in a mangrove forest

Center for Environmental Biology and Ecosystem Studies

The Center for Environmental Biology and Ecosystem Studies (CEBES) was established as a new research center at NIES on 1 April 2011. It is expected to assume a leading role in the nation's basic and applied research in the area of environmental biology and ecosystems. CEBES collaborates with national, prefectural, and local agencies, non-governmental organizations, and universities to help accumulate the scientific knowledge and data needed to conserve biodiversity and ecological services.

As the center responsible for leading one of the five Priority Research Programs in place at the institute – the Biodiversity Research Program – CEBES is taking an active part in implementing the third NIES 5-year plan. CEBES is also studying ecosystem management in the Mekong River watershed in partnership with the NIES Center for Regional Environmental Research. Furthermore, using competitive funds, CEBES researchers are conducting fundamental biodiversity and ecosystem conservation studies. It has also started research into the effects of the Great East Japan Earthquake on ecosystems.

In addition to research, CEBES conducts long-term environmental monitoring of lakes. It also preserves biological resources such as the genetic materials of microalgae and endangered wildlife species and develops and manages biodiversity databases.

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 a scientific basis. Our task is 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 prediction, and elucidate the effects of anthropogenic disturbance on biodiversity and find ways of managing these effects. The following are examples of our progress in FY 2011.

1. 1. Integration of land-use/cover data

Land-use and land-cover data are essential to estimate the spatial distributions of biodiversity and ecosystem services. Although many data and maps are available in Japan, there are substantial variations in characteristics such as publication year, spatial resolution, and land-use/cover classification categories. We searched existing public national data in Japan published by government sectors and researchers and evaluated their characteristics (Fig. 1). We then reviewed user needs (e.g., temporal coverage, spatial resolution, and classification categories) to shape our estimations of the state of biodiversity and ecosystem services. Our next steps will be to integrate the information we have gathered and develop a way of preparing new national land-use/cover data from existing datasets to bridge the gaps between data producers and users. We intend to determine the optimum data-collection time scales for revealing historic changes. Furthermore,

we will determine which spatial resolution is suitable for our estimations and then set the classification categories required. The resultant land-use/cover data should be very useful in research and management for conserving biodiversity and ecosystem services.

Fig. 1 Procedure used to prepare national land-use/cover datasets to estimate biodiversity and ecosystem services. ME: Ministry of the Environment; MLIT: Ministry of Land, Infrastructure, Transport, and Tourism; JAXA: Japan Aerospace Exploration Agency; and NIAES: National Institute for Agro-Environmental Sciences
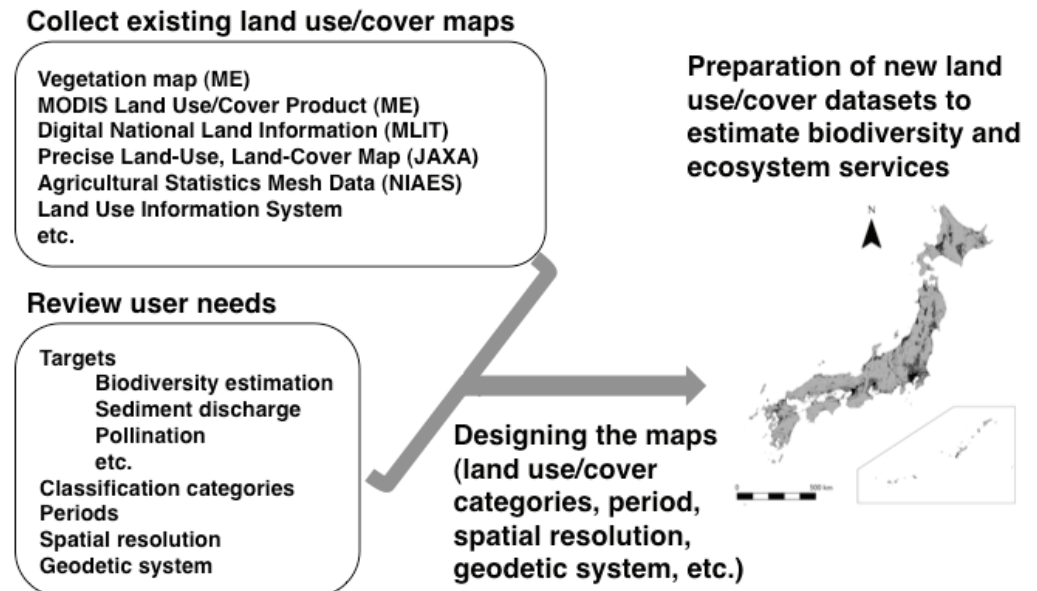
1.2. Assessing richness hotspots for threatened vascular plants in Japan

Information on the distributions of threatened species is essential for planning and implementing effective conservation strategies. However, because of the rarity and rapidly changing population sizes of such species, it is often not feasible to accumulate comprehensive data covering their whole ranges. The species distribution model (SDM) is a powerful tool for overcoming the scarcity of such data. Recently, a number of tools for using SDMs have been rapidly developed; they include the maximum entropy model, which can treat presence-only data (i.e., without absence data) effectively.

We developed SDMs for threatened vascular plants in Japan so as to facilitate further studies of spatial conservation prioritization. We modeled the distributions of 235 threatened vascular plants in main four islands, in combination with climatic, topological, and land-use variables. The plants' distribution data were extracted from a database of threatened vascular plants in Japan. The database was compiled by Japanese Society for Plant Systematics for the *Red Data Book of Japan: Vascular Plants* with the collaboration of more than 500 amateur botanists.

By compiling outputs from the SDMs that we developed, we estimated the richness hotspots for threatened vascular plants in Japan (Fig. 2, left). We also

mapped richness hotspots weighted by the extinction risk of each species, as estimated in the Red Data Book project (Fig. 2, right).

Fig. 2 Left, distributions of threatened vascular plants in Japan. Right, numbers of threatened vascular plants, weighted by the extinction risks of individual species.
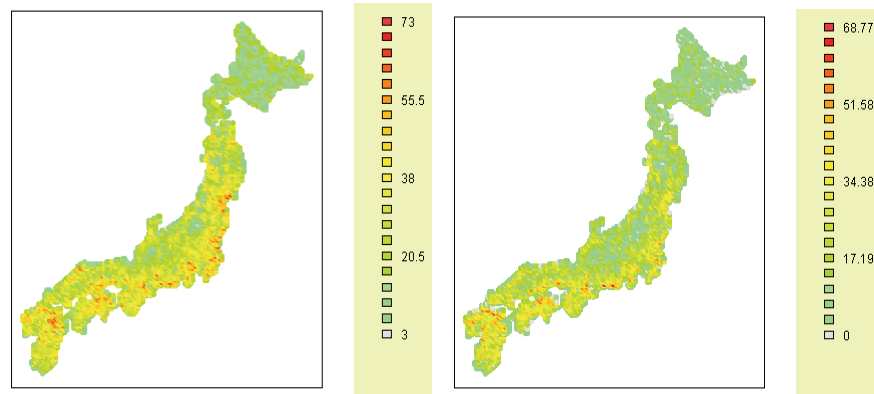
Sites with high richness shown by reddish colors tended to be concentrated in the western and southern region of the Japanese archipelago, and this trend was strengthened when the richness was weighted by extinction risk. Note, however, that the results do not necessarily imply that only the western and southern parts of Japan have high conservation priorities, because even in the northern region, where there is lower species richness, there are a number of unique species with high conservation value. We are now performing further research aimed at systematic conservation planning that takes into account these complementary aspects of conservation targets.

1.3. Control of invasive alien insects

One of our aims is to construct systems and strategies for controlling the ecological impact of invasive alien species. In 2011, we investigated the distribution of the alien bumblebee *Bombus terrestris* on Notsuke Peninsula, Hokkaido. We found that the population of the native bumblebee *Bombus hypocrite* was declining in the face of expansion of the alien species because of a strong overlap of their ecological niches. On the basis of the ecological data, we proposed a new pesticide management system for the alien bumblebee. We tested the toxicities of some insecticides against bumblebees and chose three effective ones. We are planning to test these insecticides in greenhouse experiments.

We also tested insecticidal control of another other invasive insect, the Argentine ant, *Linepithema humile*, which has become established in the Port of Tokyo area. We investigated the relationships between control efficiency and insecticide dosage. We found that the native species populations improved when the population of alien ants was controlled at optimized dose rates (Fig. 3).

Fig. 3 Temporal changes in population size of the alien ant *Linepithema humile* and native ant species in different insecticide-dosage areas.
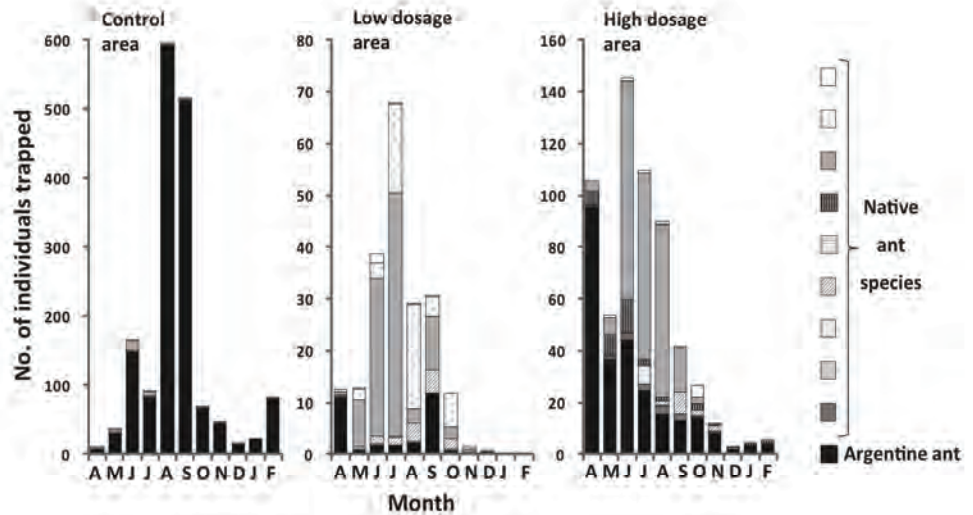
2. Fundamental Research

2.1. Key to a highly productive mangrove ecosystem: linking soil-nitrogen fixers to mangrove plant growth

Mangrove plants form highly productive ecosystems that support large biotic communities in the coastal areas of tropical and subtropical regions. Despite their important ecosystem role, however, the areas covered by mangroves have declined continuously around the world for several decades.

Plant nitrogen uptake is key to a highly productive mangrove ecosystem. Coastal habitats for mangrove plants are always exposed to tidal fluctuations, and thus nitrogen, which is one of the most essential elements regulating plant growth, is continuously exported to the ocean. Under such circumstances, bacterial nitrogen fixation is a major nitrogen input process in mangrove ecosystems. The aim of this study was to elucidate the link between soil-nitrogen fixers and mangrove plant growth.

In the mangrove rhizosphere, there is a contrast in soil nitrogen content over a small distance (10 cm) between the mangrove root zone and the root-free zone; this suggests that the mangroves retain a source of nitrogen in their root zone. We cultivated three mangrove species (*Avicennia marina*, *Rhizophora stylosa*, and *Bruguiera gymnorrhiza*) in a greenhouse in pots and monitored the soil nitrogen content of the pots compared with that in unplanted pots. During the 6-month experimental period, the amounts of nitrogen in the mangrove soils increased to four times that in the uncolonized soils (Fig. 4a). At the end of the cultivation

period, bacterial nitrogen fixation (nitrogenase activity) was significantly higher in soil colonized by mangrove plants than in uncolonized soil. Furthermore, observation of the nitrogen-fixing activity not only in the soils but also on the root surfaces revealed that mangrove plants and nitrogen-fixing bacteria likely have mutualistic link (Fig. 4b).

In a field-scale study, we measured the spatial pattern of bacterial nitrogen fixation (nitrogenase activity) in the soil around *R. stylosa* plants. Nitrogenase activity was not enhanced around the roots of juvenile-stage trees (1 m high), but it gradually rose as the plants grew. In the soil around trees at the mature growth stage (3 m high), markedly high nitrogenase activity was observed within a radius of 1 m from the tree base. These results indicate that mangrove plants are able to cope with nitrogen limitation. This ability clearly works efficiently in intertidal habitats where tidal nitrogen export occurs naturally.

Fig. 4 (a) Periodic changes in the amounts of nitrogen present in cultivated pots. Results are expressed as means ± standard error (n = 10). Different letters indicate significant differences ($P <$ 0.05) between treatmnts at the end of the experiment.
(b) Nitrogenase activity of soil and plant root materials at the end of the experiment under the four treatments:
A.m., *Avicennia marina*; *R.s.*, *Rhizophora stylosa*; *B.g.*, *Bruguiera gymnorrhiza*; Cont., control. Results are expressed as means ± standard error (n = 10). Different letters indicate significant differences ($P <$ 0.05) between treatments at the end of the experi-ment.
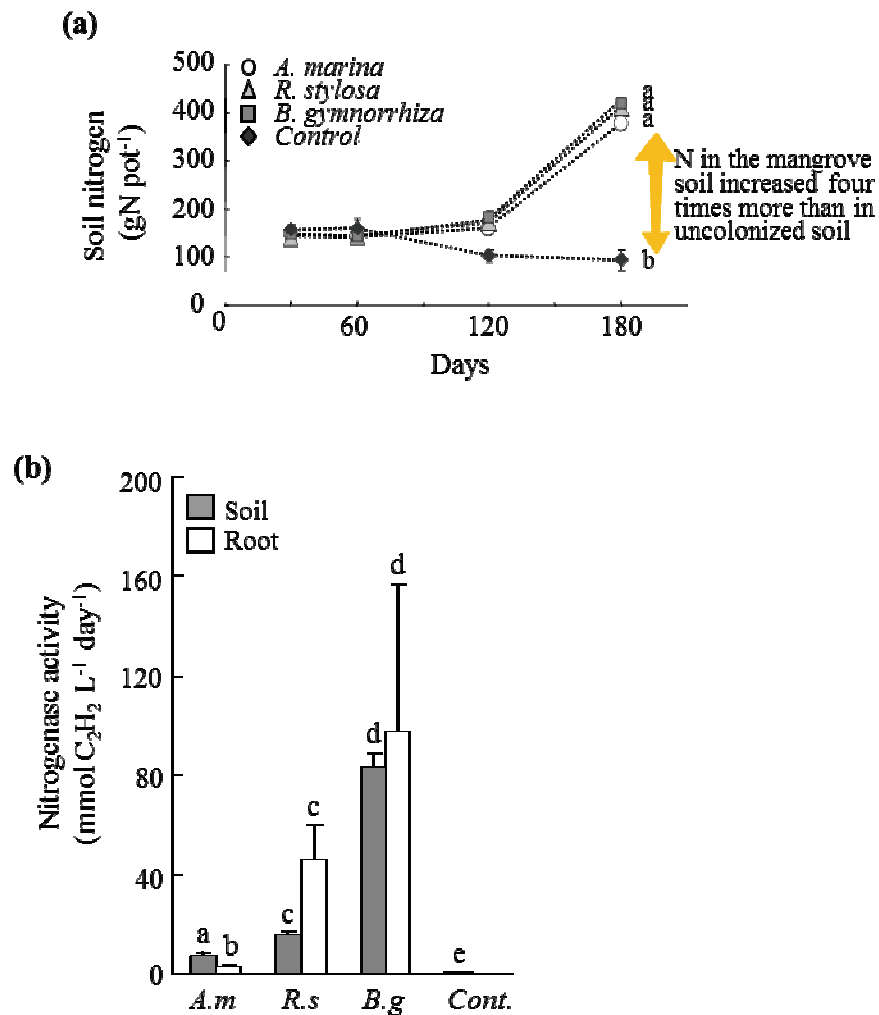
2.2. Effects of eradication of invasive species on ecosystems of oceanic islands
Eradication of invasive species is one of the most serious issues on oceanic islands. Once an invasive species has flourished and increased its biomass, careless eradication may disturb the nutrient cycle in the ecosystem and cause extinction of native species. We therefore need to devise appropriate eradication scenarios.

The Ogasawara Islands were mostly covered by forest before human colonization in the 19th century. Thereafter, on some of the islands, the forest was replaced by grassland or bare ground, mainly because of deforestation and grazing by introduced goats. Moreover, the abundance of invasive tree species (e.g. Leucaena) is increasing. Invasion by rats has caused the decline of seabird populations, and consequently the abundance of soil nutrient has severely decreased. The invasive goats have been eradicated, but efforts to eradicate rats are still continuing.

We used computer simulations to evaluate possible eradication scenarios. We constructed a model reproducing the ecosystem of Nakoudo-jima Island, and we simulated the eradications of invasive goats and rats. First, we examined the following three cases of eradication: 1) only rats, 2) only goats, and 3) both goats and rats simultaneously. In the first case, no conspicuous change in the model ecosystem was found. In the second case, the biomass of native plants increased, but the biomass of invasive trees also increased, and the abundance of soil nutrient did not increase. In the third case, both the biomass of native plants and the abundance of soil nutrient increased dramatically. In addition, the increase in abundance of invasive trees was suppressed. These results indicate that both goats and rats should be eradicated simultaneously. However, in the third case, native grass species were prone to extinction because of forest succession; we should therefore be careful to avoid this extinction.

Next, we examined the effect of the rat eradication effort when both goats and rats were eradicated simultaneously. As the eradication effort increased, the rat biomass at the end of the simulation as a ratio to that at the start decreased (Fig. 5a) and the abundance of soil nutrient increased monotonically. On the other hand, the effect on native grass species was complex. As the rat eradication effort increased, the surviving native grass species at the end of the simulation as a ratio to that at the start initially decreased (Fig. 5b). When the eradication had no effect on rat biomass (i.e. rat biomass ratio = 1), the ratio of surviving grass species was close to its minimum (Fig. 5b). However, beyond a certain point, the ratio of surviving native grass species began to increase with increasing intensity of the rat eradication effort. These results indicate that strong eradication efforts are preferable.

Finally, we examined the effect of the duration of the rat eradication effort when both goats and rats were eradicated together. In this simulation, the rat eradication

effort was fixed to 3.0 (see Fig. 5). The simulation results indicated that the ratio of surviving native grass species decreased as the duration of the eradication effort increased. This result may have occurred through the following process. As the rat eradication effort continues, the biomass of native animal and plants increases, which means that the abundance of food available for the rats increases. At the same time, succession to forest proceeds; consequently, the habitat for grass declines. If the rat population were still surviving when the eradication effort was interrupted, it would grow explosively. Therefore, under this model, several native grass species would become extinct because of the rapid increase in grazing pressure from the rat.

This study suggests that 1) goats and rats should be eradicated simultaneously, 2) the rat eradication effort should be intensive enough to eliminate the rats, and 3) the rat eradication effort should be continued until the rats are completely eliminated.

Fig. 5 Changes in rat biomass and ratio of surviving native grass species with increasing intensity of the rat eradication effort. The vertical axis in (a) represents the ratio of the rat biomass at the end of the simulation to that at the start. If the ratio is equal to 1, the rat biomass does not change, despite the eradication effort. The vertical axis in (b) represents the ratio of surviving native grass species at the end of the simulation compared with that at the start. Each plot shows the mean of 100 simulations.
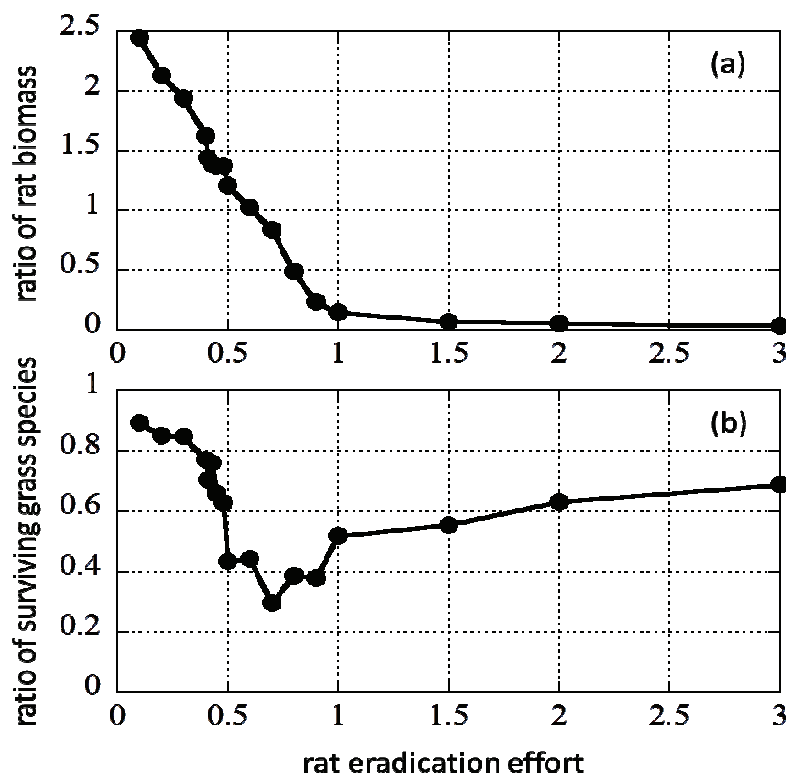
3. Lake Kasumigaura Long-Term Environmental Monitoring Program

Long-term monitoring is needed to assess the state and direction of change in ecosystems, to distinguish directional trends from short-term variability, and to determine the effects of infrequent, extreme events and time lags in response.

Since 1977, we have been conducting monthly monitoring at Lake Kasumigaura, the second-largest lake in Japan. We measure selected environmental variables (water temperature, water depth, transparency, dissolved oxygen, pH, and light intensity in the water), water quality (electronic conductivity, chemical oxygen demand, chlorophyll a, suspended solids, particle organic carbon, particle organic nitrogen, particle organic phosphorus, total phosphorus, dissolved total phosphorus, soluble reactive phosphorus, total nitrogen, dissolved total nitrogen, nitrate nitrogen, ammonium nitrogen, Al, B, Ba, Ca, Fe, K, Mg, Mn, Na, Si, Sr, and Cu), plankton (bacteria, heterotrophic nanoflagellates, ciliates, picocyanobacteria, eukaryotic picoplankton, phytoplankton, rotifers, crustacean zooplankton, mysids), benthos (chironomids and oligochaetes), and primary production. The database for this monitoring program is released on the following website:

http://db.cger.nies.go.jp/gem/moni-e/inter/GEMS/database/kasumi/index.html

This lake is registered as a core site of JaLTER (the Japan Long-Term Ecological Research Network). It is also a Monitoring Site 1000 of the Ministry of the Environment and a trend-monitoring station of the United Nations Environment Programme's GEMS (Global Environment Monitoring System) Water Programme.

In 2011, we newly released fish monitoring data on our web database. Our data showed that non-native fish species account for an average of 45% of the fish assemblage by number. The channel catfish (*Ictalurus punctatus*), which is indigenous to North America and was introduced into Japan in 1971 for aquaculture, still has a large biomass (Fig. 6). The catch per unit effort of other invasive fishes, such as largemouth bass (*Micropterus salmoides*) and bluegill sunfish (*Lepomis macrochirus*) has tended to decrease over the last 5 years (Fig. 6). Because the channel catfish is an extremely physiologically tolerant, omnivorous, and opportunistic feeder, and larger individuals are piscivorous, it may have negative impacts on native species and commercial fisheries, as well as cascading effects on multiple ecosystem goods and services.

The nuclear accident at the Fukushima Daiichi nuclear power plant that accompanied the Great East Japan earthquake and tsunami on 11 March 2011 resulted in enormous amounts of radionuclides emitted into the atmosphere and the ocean. Radioactive fallout was also detected in the water and in some organisms sampled in Lake Kasumigaura. By taking advantage of our research platform and long experience, in July 2011 we started monitoring to investigate the behavior and biological accumulation of radionuclides within the lake ecosystem. We collect plankton, emergent macrophytes, mussels, snails and fish two to four times a year and measure their radiocesium concentrations. Fukushima-derived ^{134}Cs and ^{137}Cs have been detected in these samples. Further long-term monitoring at a watershed scale is needed to understand the long-term behavior of radionuclides through the lake's food web and to explore the underlying mechanisms of the long-term decay processes.

Fig. 6 Temporal changes in catch per unit effort (CPUE) of three non-native fish, designated as Invasive Alien Species by the Ministry of the Environment of Japan, in Lake Kasumigaura.
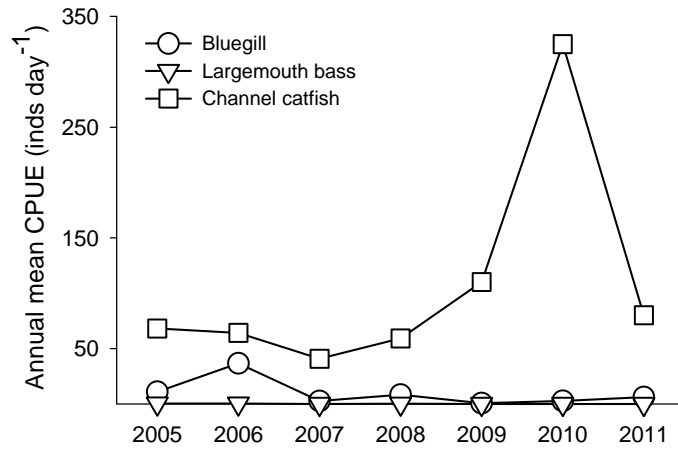
Center for Environmental Health Sciences
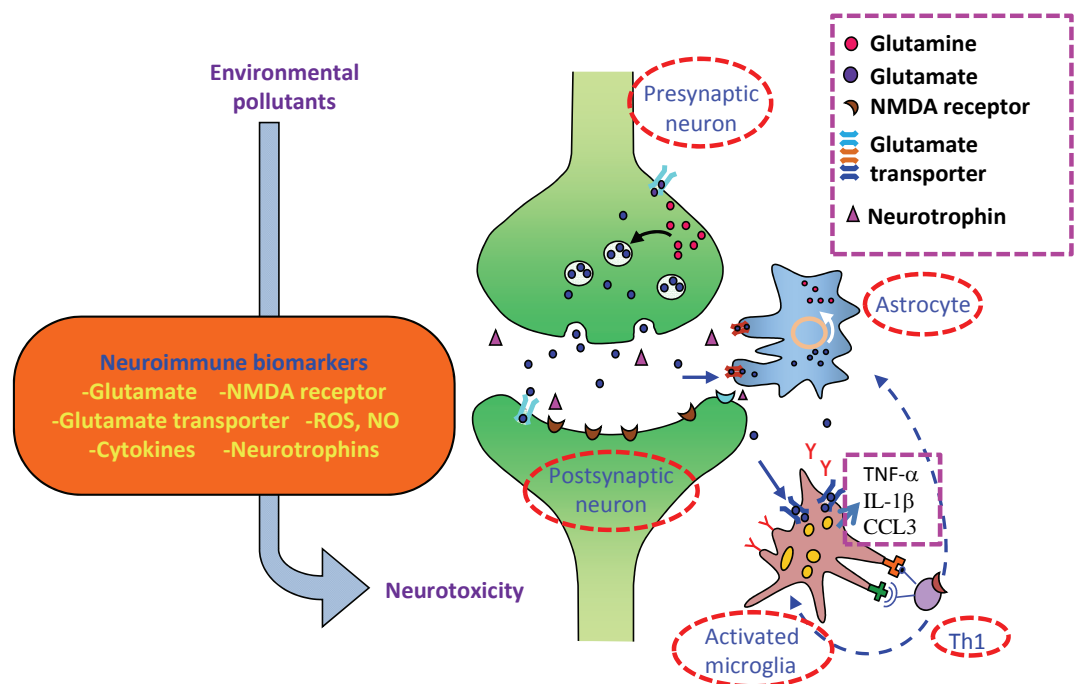
Potential neuroimmune biomarkers in the brain after environmental pollutant exposure in a mouse model

Environmental pollutants can be translocated to the mouse brain directly via the olfactory nerve or systemic circulation. They may then induce glutamate secretion from presynaptic neurons. Excessive amounts of glutamate cause neurotoxicity and may abnormally activate postsynaptic NMDA (N-methyl-D-aspartate)-type glutamate receptors. These pollutants may also activate the neuroimmune system—especially microglia. The activated microglia may secrete proinflammatory cytokines and chemokines (IL-1β, TNF-α, CCL3), reactive oxygen species, and other toxic substances, such as nitric oxide. Immune cell–like Th-1-type T cells may "talk" to the microglia and secrete pro- or anti-inflammatory cytokines, depending on the type of message received The clearance system of astrocytes, which participates in the reuptake of glutamate, is activated to reduce toxic glutamate levels. When environmental pollutants induce excessive secretion of proinflammatory cytokines and the excitatory neurotransmitter glutamate, and the production of other toxic substances, these events may lead to neurodegeneration and learning deficits. However, efficient compensatory mechanisms mediated via neurotrophins can reverse these neurotoxic effects. The neurotoxic effects of environmental pollutant exposure may differ among individuals, depending on their sensitivity to neuroimmune biomarkers.

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

We therefore intend to experimentally elucidate 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 the impacts of the environment on health and the factors underlying them.

Specifically, we intend to assess the 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 the health impacts of such environmental factors and their mechanisms of action, with a focus on genomics and epigenetics. In addition, we aim to work on the epidemiological assessment of these health impacts and to try to integrate, systematize, improve, and refine this assessment.

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

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

We intend to promote a pilot study program, namely the **Research Program on Environmental Health for Children and Future Generations.** This program will also be used by JECS.

A wealth of information is likely to be obtained from the JECS. We will need to expand on the survey results, for example, by biologically validating the epidemiological findings through elucidation of the health impact mechanisms or by suggesting target substances or impact indices that should be epidemiologically considered from among the enormous numbers of environmental pollutants and other health impact factors.

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

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

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

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

- With children and the next generation as the primary targets, we will elucidate the impacts of environmental pollutants on immunological and allergic diseases by using animal disease models and cell lines. 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 2011 were as follows.

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

We investigated several parameters of the immune system and central nervous system after intratracheal exposure to di(2-ethylhexyl)phthalate (DEHP) in a childhood asthmatic mouse model. Although DEHP exposure tended to increase the numbers of inflammatory cells (neutrophils, eosinophils, and monocytes) in the lung and tended to increase lung expression of antigen-presenting cell markers (MHC class II, CD11c) (Fig. 1) compared with ovalbumin (OVA) group, no marked effects of DEHP exposure were observed. Unlike with the results we reported last year for benzo[a]pyrene (BaP), the effects of intratracheal exposure to DEHP on childhood asthma might be weak.

We investigated comprehensive gene expression, phenotypes, and cytokine production in immune cells after *in vitro* exposure to environmental chemicals. Exposure to BaP, but not to bisphenol A, stimulated the expression of genes associated with immunological reaction and biological defense in mouse bone marrow–derived dendritic cells (BMDCs). We observed either common or characteristic changes in BMDCs exposed to BaP or phthalates (DEHP or diisononyl phthalate). Exposure to nitro- or amino-polycyclic aromatic hydrocarbons (PAHs) as ambient particulate matter components induced inflammation-related activation of mouse immune cells (splenocytes and BMDCs) and human bronchial epithelial cells. These results, together with those of previous studies, suggest that the biological effects of PAHs are related to the presence of structural chemical features such as functional groups and isomers.

We investigated the effects of exposure to nanoparticle-rich diesel exhaust (NRDE) for 3 months on hippocampal-dependent spatial learning ability and

memory function–related gene expression in BALB/c female mice. We found that high-dose NRDE exposure impaired hippocampal-dependent spatial learning ability (Fig. 2) and led to the upregulation of N-methyl-D-aspartate (NMDA) receptor expression in the hippocampus. These findings indicate that NRDE induces neurotoxicity in the mouse by modulating NMDA receptors in the hippocampus. To investigate the role of toll-like receptor 4 (TLR4) in hippocampal neurotrophin expression, C3H/HeN (TLR4-intact) and C3H/HeJ (TLR4-defective) male adult mice were given diazinon (0, 0.05, 0.5, or 5 mg/kg) intraperitoneally once a week for 3 weeks. The levels of expression of NGF (nerve growth factor) and BDNF (brain-derived neurotrophic factor) mRNAs were suppressed significantly in the diazinon-injected C3H/HeJ mice compared with their control group, but not in C3H/HeN mice. These results suggest that defective TLR4 signaling pathways in the mouse hippocampus are easily affected by diazinon administration.

Fig. 1 Cellular profiles in bronchoalveolar lavage fluid following exposure to di(2-ethylhexyl)phthalate (DEHP) in mice with allergic asthma.
(A) Differential cell counts. Data are means ± SE of 9 to 13 animals per group (*$P < 0.05$, **$P < 0.01$ vs. vehicle group). (B) Expression of CD11c, a dendritic cell marker. Data are means ± SE of two samples pooled from three animals per group.
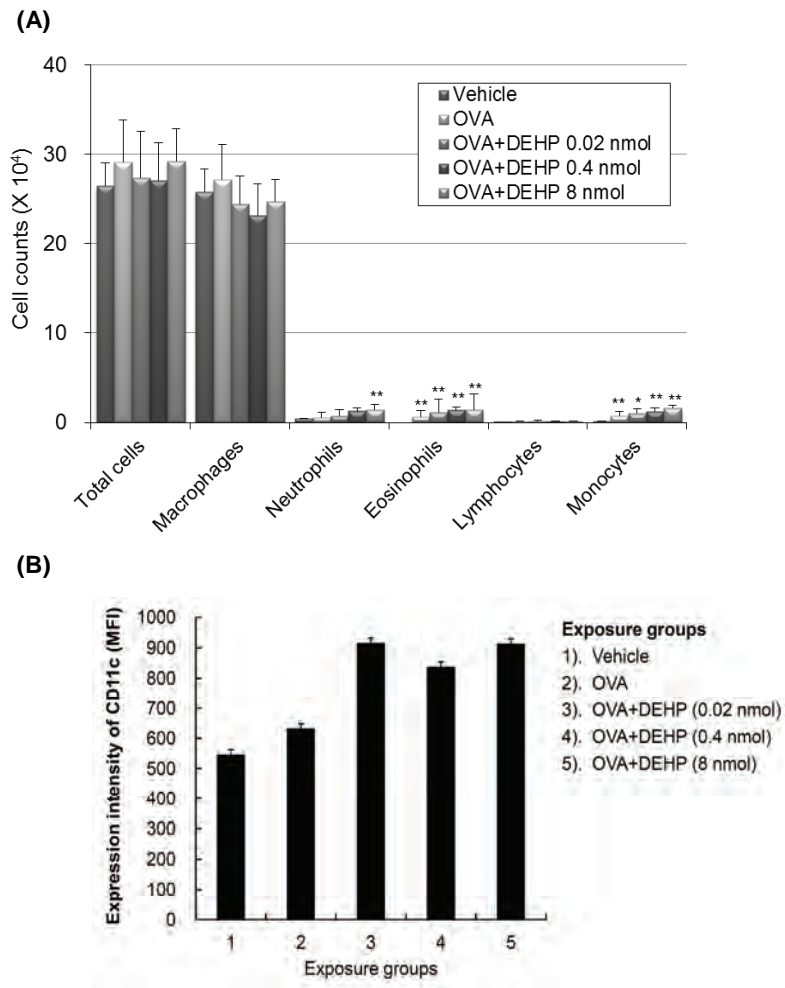
Fig. 2 (A) Morris water maze apparatus for investigating spatial learning ability, and (B) spatial learning performance during the acquisition phase of mice exposed to clean air, M-NRDE [medium-dose NRDE], H-NRDE [high-dose NRDE], or F-DE [filtered H-NRDE] for 3 months. Escape latency indicates the time required to reach the hidden platform. Each bar represents the mean ± SE (n = 6) (*P < 0.05 vs. clean air group).
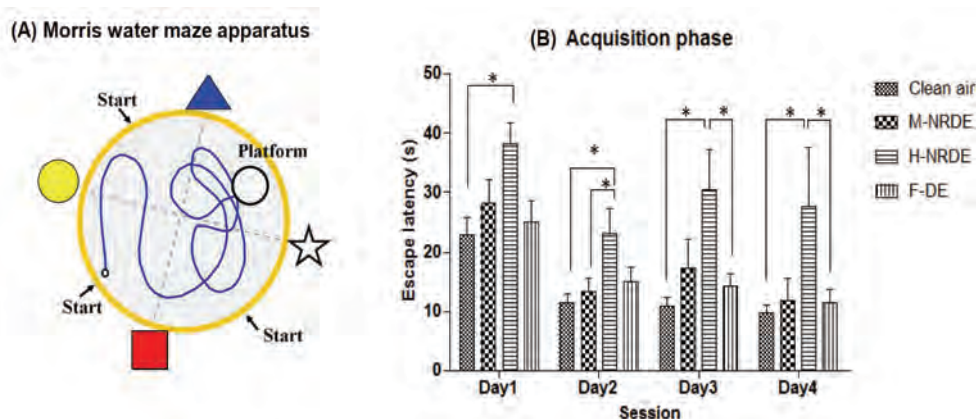
In the **Molecular Toxicology Section,** we have been studying the effects of environmental chemicals on biological and physiological functions and molecular mechanisms, including epigenetics.

In FY 2011, our focus was on the adverse health effects of inorganic arsenic. Naturally occurring inorganic arsenic has been contaminating drinking-well water and causing serious health problems, including cancer, in many areas of the world. The central nervous system and immune system have emerged as targets of arsenic.

Perinatal arsenic exposure increases the incidence of hepatic tumors in adult male offspring of C3H mice. We explored the tumor-promoting changes resulting from arsenic exposure in this mouse model. We found that perinatal arsenic exposure increases the expression of the mRNAs of several genes, including the oxidative stress–inducible gene *HO-1* (*heme oxygenase-1*), and of retrotransposon L1 in a late-onset manner; this likely leads to genomic instability and tumor augmentation.

We conducted an MeDIP-array (methylated DNA immunoprecipitation-array) assay on hepatic tumors in control mice and in mice that had been exposed perinatally to arsenic. We identified several regions where the DNA methylation status differed between the tumors in the control group and the arsenic group. These results suggested that the methylation status of DNA could be a promising marker of tumors resulting from arsenic exposure.

We performed both *in vivo* and *in vitro* animal experiments to investigate the mechanism by which arsenic adversely affects the central nervous system. In the *in vivo* model, we developed a behavioral task for detecting behavioral flexibility in mice in an IntelliCage (NewBehavior AG, Zurich, Switzerland). We used the task to evaluate the effect of arsenic on the learning behavior of mice exposed prenatally to arsenic. In the *in vitro* model, we established primary cultures of neurons and astrocytes taken from perinatal mouse brains and evaluated the effects of arsenic on cellular morphology and gene expression.

In our exploration of the mechanism of arsenic-induced immune suppression, we found that long-term culture of a mouse lymphoid cell line increased the expression of the mRNAs of enzymes involved in inducing mutations and suppressed the expression of the mRNAs of oxidative stress–induced DNA damage–repair enzymes. We further found that long-term culture with arsenic increased the abundance of cells detected by senescence-associated β-gal staining. These results suggest that long-term arsenic exposure triggers senescence—and thus irreversible suppression of cellular growth—by increasing the frequency of mutations.

The **Environmental Epidemiology Section** has been 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.

- As part of an MOE project to assess the health effects of air pollutants, we explored the short-term effects of photochemical oxidant (Ox) by using data from 20 Japanese cities.
- Ox was associated with all-cause mortality and with cardiovascular and respiratory mortalities. The association was particularly evident during spring and autumn.
- We are also involved in a project to assess the health impact of climate change in the Kanto area. Figure 3 shows the spatial distribution of excess mortality due to heat in the Kanto area in August 2007.
- Our current focus includes the health effects of long range–transported air pollutants and of local air pollution. We found an increased risk of emergency ambulance dispatches in Nagasaki during Asian Dust events.
- We performed an exposure assessment of particulate matter (PM) and examined the association between PM concentrations at a fixed site and personal PM exposure.
- Using a cohort of over 90 000 individuals, we examined the association between temperature and cardiovascular mortality. The results suggested that exposure to cold temperatures increases the risk of cardiovascular deaths.

Fig. 3 Distribution of excess mortalities due to heat in the Kanto area in August 2007 (persons per square kilometer).
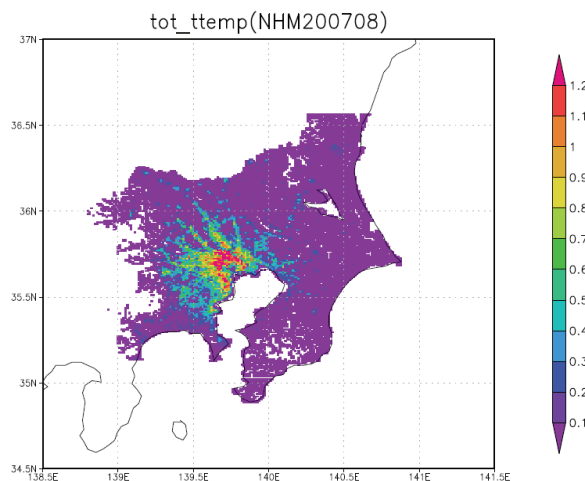
The **Integrated Health Risk Assessment Section** conducts research that bridges exposure science and epidemiological studies. The research consists of the development of an integrated exposure assessment methodology using bioassays and analytical chemistry, a field survey to formulate a food frequency questionnaire (FFQ) for young children, development and application of a method of high-throughput targeted and non-targeted analysis of environmental and biological samples, and exposure assessment using mathematical models. We work with a number of national collaborators, as well as with a multinational and multidisciplinary research team that includes the US Environmental Protection Agency, EU partners, and Asian institutions. Our study of integrated exposure assessment aims to develop a generalized mode-of-action–based toolkit for evaluating environmental samples such as wastewater effluents and surface waters. The goal of the FFQ and the development of a targeted/non-targeted analytical method is ultimately to contribute to the currently running large-scale birth cohort study (namely the JECS mentioned above) as tools for evaluating children's nutritional conditions and estimating exposure to environmental chemicals.

The **Planning and Coordination Office** and the **Data Management and Analysis Office of the Children's Environmental Health Study** have played key roles in JECS. In FY 2010, these offices began preparing standard operating procedures for participant recruitment; facilities/equipment/personnel for transport, storage, and management of collected data and specimens; support for regional Unit Centers; a system of communication between the Centers and participants; and various advertisements. JECS is a nationwide newborn cohort study that involves the recruitment of women in early pregnancy and follow-up of their children until age 13. The goal of the study is to help us to understand the roles of various environmental factors in children's health and development.

Center for Social and Environmental Systems Research

Opening statement by President Jacob Zuma (South Africa)
at the COP17 opening plenary session.
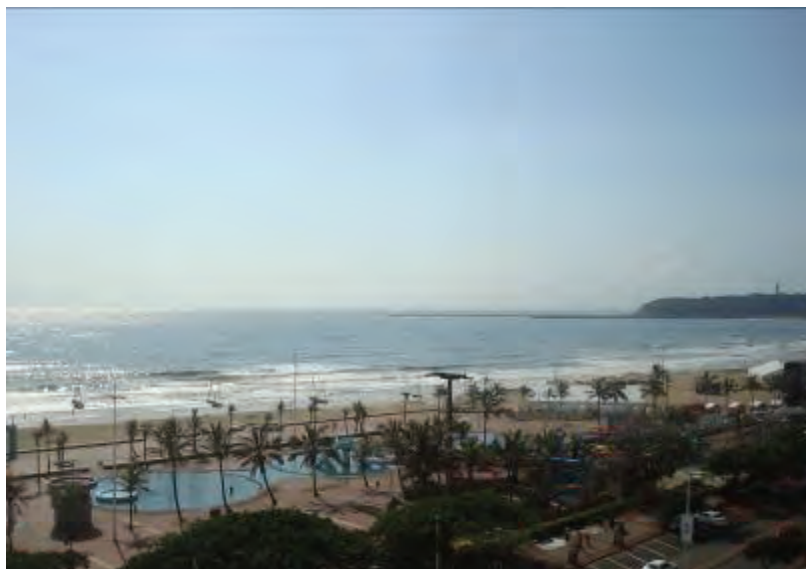
The beautiful scenery of Durban, South Africa. Photos: Izumi Kubota.

The Center for Social and Environmental Systems Research targets linkages between human activities and the natural environment to clarify the relationships between socioeconomic systems and environmental issues. The work of the Center results in proposals for environmental policies and a sustainable society. It covers a broad area, from global environmental issues such as global warming to local issues like recycling and lifestyle. 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 planning and evaluation techniques and applications relating to environmental conservation, including local goal-setting for environmental policies, and on the prediction and assessment of climate change impacts.

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) and the achievement of a low-carbon society in the long term without harming our economy.

5. The Eco-City System Research Section analyzes urban and regional environmental goals such as low-carbon cities and sustainable transportation systems.

Our main research outcomes in FY 2011 were as follows.

1. Environmental Economics and Policy Section

To investigate various environmental issues, we are studying the interactions between current social and environmental systems by using approaches from social science, natural science, and systems analysis. In addition, we are analyzing the economic impacts of environmental policies such as carbon taxes and emissions trading. We are also analyzing environmental policy decision-making processes in use by various countries and investigating the possibility of international cooperation on global environmental conservation.

(1) Financing adaptation: Challenges in allocating funds to vulnerable countries

Streamlining and scaling-up of financial support is a key area that we need to focus on to enhance measures for adaptation in the post-2012 framework. One of the achievements of the United Nations Framework Convention on Climate Change (UNFCCC) negotiations in Cancun (COP16/CMP6) (2010) was the decision to establish a Green Climate Fund. With the securing of an agreement on the fund, the question of how to develop a transparent way of prioritizing countries for fund allocation has once again raised. To determine the implications of the mechanisms used to prioritize future adaptation finances, we analyzed how the Pilot Program for Climate Resilience (PPCR) and the Adaptation Fund under the Kyoto Protocol select target countries or projects. The Adaptation Fund and

the PPCR have their own merits and drawbacks. We found that it is essential to adopt various types of funding systems in future climate change adaptation support so that the funds supplement each other and the benefits they provide are maximized.

(2) Study of perceived flood damage cost in the Tokyo Metropolitan Area

Future climate change is likely to bring an increased frequency of natural disasters, including flooding. Much attention has therefore been paid to flood adaptation policy. Estimating the benefits of reducing flood damage is important in developing cost-effective adaptation policies. In previous estimates of such benefits there has been concern about the omission of variable bias in estimating flood damage. In this study, we developed a hedonic land price model by employing two-step procedures to correct the bias in flood hazard estimates. We found that previous studies were likely to have underestimated the perceived flood damage. In addition, flood risk was estimated to lower land prices by 10.24% (an average reduction of 143,946 yen/m^2 [approximately US$1,810], and the perceived flood damage was estimated to be 1,196,209 yen/m^2 (approximately US$15,040/m^2). This estimate was larger than the estimate produced by the Tokyo metropolitan government, indicating that the indirect damage cost is likely to be much higher than the direct damage cost (i.e. the cost estimation based on physical damage alone).

2. Environmental Planning Section

We are studying the development and assessment of regional plans and basic environmental plans for environmental conservation. In this section, we are investigating new methods of understanding and assessing regional environments. We are also investigating the current status of public environmental awareness and promoting voluntary action by individuals.

(1) Theory and effects of voluntary environmental actions taken by individuals and enterprises

In the search for ways to encourage participation in voluntary activities, more attention is being given to what motivates people to participate. In empirical studies, however, the relationship between motivation and participation in voluntary activity has not yet been made clear. To understand how to facilitate more effective recruitment of volunteers, we studied the differences in participatory factors among different types of voluntary activity. We used data from a web survey to analyze the relationships between (1) motives, (2) social background factors such as gender, (3) economic elements, and (4) the type of voluntary activities in which people seemed to want to participate. Each voluntary activity was associated with different motives and social backgrounds. It should therefore be possible to select the types of voluntary activities in which recruits would be interested according to their motives for participation and their social background elements.

(2) Study of national trends in public interest in environmental issues

We conduct ongoing monthly public opinion surveys to evaluate the levels of public support for environmental policies. These surveys have included perceptions of the 2011 Great East Japan (Higashi Nihon) Earthquake disaster in the Tohoku region. Our questionnaires cover "the world's most important issues" and "Japan's most important issues." Our sample populations consist of 4000 men and women who are drawn from across the nation and aged at least 20 years. Respondents are randomly selected every month, and in each month, we usually obtain more than 1000 responses.

Figure 1 shows the results of a survey Japan's most important issues, with special reference to the Tohoku region. Since summer 2008, the public has endured unemployment and a weak economy as a result of the Global Financial Crisis. At the time of the Tohoku earthquake, the Japanese people were still struggling with a weak economy, and the situation in Tohoku was worse than the national average. The response rate for "economy/employment" in January 2011 was higher in the Tohoku region than in all others. Surprisingly, just after the disaster, in May and June 2011, the rate of response citing the Tohoku disaster as Japan's most important environmental issue was lower than in other regions; the peak came in September 2011, as the economy/employment gradually took over. Economy/employment and the Great East Japan Earthquake disaster were still the top issues in March and April 2012, one year after the disaster. This disaster therefore has had, and will continue to have, a strong impact on Japanese society, and it will take many years to overcome its effects.

Fig. 1 Changes in public perception and mass media coverage from January 2008 to April 2012, with special reference to the Tohoku region
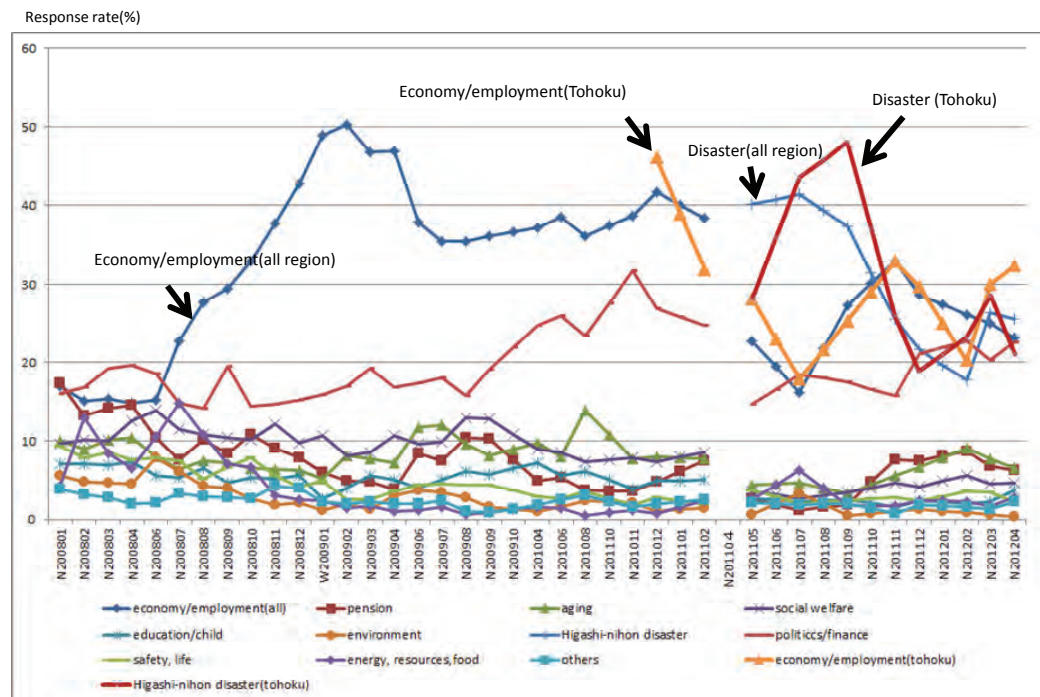

Fig.1 Changes of public perception from January 2008 to April 2012, with special referene to Tohoku Region (Response rate of "The most important issue in Japan")

(3) Outdoor experiment on differences in surface temperature with changes in clothing color

The effects of reflectance of solar radiation have been well studied in terms of the paints used on paving and on building surfaces. However, there is insufficient information on reflectance in terms of clothing color, which is important for outdoor thermal comfort. Moreover, since the Fukushima nuclear power plant accident in March 2011, there has been an emphasis on the need to save on electricity use by limiting air-conditioning in summer.

We used infrared thermography to observe surface temperatures of polo shirts of the same material and design but different colors; the shirts were hung in unshaded outdoor open space on the campus of NIES, Tsukuba, on sunny days in August 2011. Color brightness is considered to represent the reflectance of visible light. We found that the brightness values (no dimension; 0 to 1) changed with changes in RGB balance and were 1.0 (white), 1.0 (yellow), 0.9 (grey), 0.8 (red), 0.7 (blue), 0.6 (green), 0.4 (purple), 0.4 (dark green), and 0.1 (black) (Fig. 2). In the early stage of this observation (morning), the order of the colors in terms of the observed surface temperatures was nearly exactly the reverse order of the color brightness values. Brightness is an important determinant of solar radiation albedo, which in turn determines surface temperature. The maximum difference between black and white was almost 20 °C and was greatest when the solar radiation was strong. However, the differences became smaller in the later stages of our observations (afternoon). Reflection performance in the near-infrared band is also an important determinant of surface temperature.

Fig. 2 Outdoor monitoring of surface temperatures of polo shirts of different colors but the same material and design during exposure to solar radiation (8 August 2011). There was an obvious inverse correlation between color brightness and measured surface temperature. For both good health and reduction of air-conditioning use, we need to choose clothing colors wisely.

Color	Brightness	R	G	B
Black	0.10	26	26	26
D-Green	0.37	0	94	38
Purple	0.43	61	0	110
Green	0.62	0	158	73
Blue	0.70	0	65	179
Red	0.78	199	0	36
Grey	0.88	224	224	224
Yellow	0.99	254	220	0
White	1.00	255	255	255
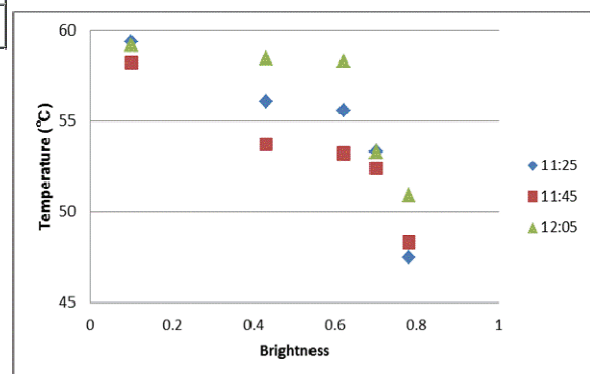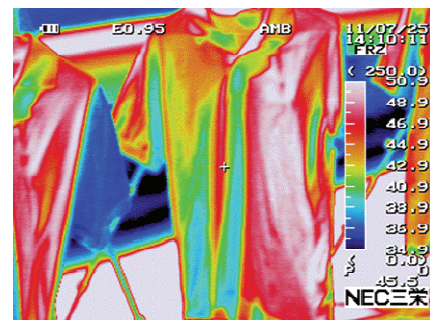
3. Integrated Assessment Modeling Section

"Integrated assessment" is a framework for linking the policymaking process with scientific knowledge from a wide range of disciplines. The core tool in integrated assessment is a model that evaluates policy options for solving various environmental problems. We have developed and modified the Asia-Pacific Integrated Model (AIM) to assess climate and other environmental policies. The spatial coverage in the models we have developed ranges from the local scale to the global scale. We are expanding the AIM to include not only climate problems, but also assessment of sustainable development. The following three topics were our main activities in 2011.

(1) Development of a global integrated model and quantitative scenarios

We have been developing new scenarios named SSPs (Shared Socioeconomic Pathways). This scenario framework has a total of five scenarios with two dimensions, namely challenges for mitigation and adaptation. To quantify the scenarios, we have developed a global energy economic model. In addition to energy systems, agriculture is taken into account in this model because it is an important climate-impact research area. By linking a crop model to the global energy economic model, we are assessing the global climate change impact on agricultural productivity and, in turn, on food security, people at risk of hunger, and macroeconomic activity. Differences in socio-economies, climate conditions, and the availability of adaptation strategies are taken into account in our comprehensive analysis of climate impact on the agricultural sector. The results have provided three insights: (1) socioeconomic conditions are a fundamental determinant of food security and people at risk of hunger, particularly in the developing world; (2) climate impact is also a crucial factor; and (3) adaptation can offset the negative impacts of climate change.

(2) Development of a climate impact assessment model

Recently, a considerable number of climate change impact analyses have explicitly taken into account a plausible range of greenhouse gas (GHG) emissions and uncertainties in their global climate projections. However, for impact analyses at the national, sub-national, and local scales, spatial downscaling of climate projections is usually a necessary exercise and could be a source of uncertainty. We estimated climate change impacts on beech forests in Japan by the end of the 21st century; we considered the uncertainties derived from the choice of a regional climate model for spatial downscaling, in addition to the uncertainties in emission scenario and climate sensitivity. To estimate potential habitat for beech forests under future climate scenarios, we used the ENVI model, which is a statistical model for evaluating the probability of the existence of beech forest in each grid cell of 1 km × 1 km spatial resolution. The uncertainty in the projected area suitable for beech forest, as derived from the choice of regional climate model, was smaller than that derived from the choice of a global climate model with different climate sensitivity. However, the difference in the projected area suitable for beech forest among the choices of

regional climate model was not negligible at the local scale.

(3) Development of a Population and Household Dynamics Model

We have developed a Population and Household Dynamics Model as a type of AIM model to estimate future populations and numbers of households to provide a common projection of social index to other AIM models. For population projection the model covers 197 countries; populations by sex, age group, and urban/rural area were estimated by using the cohort-component method. For household projection, the numbers of households by sex and age group of householder and urban/rural area were estimated by using the headship rate method which is typically used by UN habitat and demographic researchers. With the progress of urbanization in both developed and developing countries, 80% of people in Japan, 73% of people in China, and 54% of people in India will live in urban areas by 2050. Additionally, populations in Asia are rapidly aging. The household projection revealed that the average number of household members will decrease in almost all countries. Therefore, despite the decline in population, the number of households in Japan will not decrease substantially by 2050. In contrast, in some Asian countries, such as India, Indonesia, and Malaysia, increases in population and decreases in the average number of household members will lead to rapid growth in the number of households.

4. Sustainable Social Systems Section

Staff in this section mainly lead research projects related to climate change. In doing so, our intention is to deal not only with climate change itself, but also with related ecological and economic principles and values, so that the outputs of our studies are directed toward a sustainable future for our society. What is a low-carbon society? How can we achieve a low-carbon society in the long term without harming our economy? What kinds of adverse impacts of climate change are likely to occur in the absence of mitigation efforts? To what degree can we adapt to the new climate? How can we arrive at a multilateral agreement to alleviate the adverse effects? These are some of the research questions we are addressing.

(1) Creation of energy and climate change scenarios for Japan

We used the AIM model to assess energy and climate change scenarios after the Fukushima nuclear power plant accident. Our results showed that 25% GHG emission reduction target can be achieved by 2030 even without the use of any nuclear power plants, and that the incremental investment cost for achieving the target can be recovered by energy saving. If we can evaluate non-energy benefits such as the enhancement of quality of life, then the measures implemented for GHG reduction should have higher value. Our results were used as the basis of debate in the Global Environment Committee, Central Council of the Environment and The Energy and Environment Council, Japan.

(2) Creation of low-carbon-society scenarios for Asian countries

The AIM was also introduced into studies of Asian countries such as China, India, Korea, Malaysia, Thailand, Indonesia, Vietnam, Bangladesh, and Cambodia to develop country-wise and city-wise low-carbon-society scenarios. Specifically, a simulation analysis based on the AIM/Regional Distributed Energy System Model (AIM/ESM[Distributed]) was used to assess the feasibility of low-carbon systems of regional electricity supply using renewables in Iskandar, Malaysia. The simulation analysis investigated the hourly demand–supply balance of electricity. The renewable systems covered by AIM/ESM[Distributed] are photovoltaic, wind-turbine, biomass, and mini-hydro; electricity supply from these renewables is determined on the basis of meteorological conditions and maximum potentials, as well as by the capacity of the system.

The results revealed that renewable energy would not be installed in Iskandar if there were no policy incentives or targets, or both, for the installation of renewables in the region, even if the analysis took into account future reductions in the capital cost of renewables. Nevertheless, the analysis showed that, if incentives were in place in Iskandar, the model targets for the introduction of renewable energy would be effective in increasing the installation of renewables—especially photovoltaic systems Depending on the assumptions of future electricity demand, CO_2 emissions would be reduced by 2% at most compared with the cases if renewable were not used.

(3) Research on climate change impact and adaptation

To incorporate the results of research on sectoral impact assessment into an integrated impact assessment model called AIM/Adaptation[Policy], we collected information on indicators for quantitative impact assessment, as well as on the climate parameters used for model analysis and the adaptation methods used in the various sectoral impact assessment model. The results of an impact assessment of heat-stress mortality risk in the Tokyo Metropolitan Government (TMG) area were incorporated into AIM/Adaptation[Policy] and its operation was checked. We found that the model worked and was problem-free. Another of our studies was a comprehensive assessment of climate change impacts in the TMG area. The results quantified the sectoral, spatial, and temporal vulnerabilities in the TMG area; this information could be useful for formulating adaptation policies.

(4) International institutions for beyond 2012

Long-term international cooperation for both climate change mitigation and adaptation actions is being negotiated at a multilateral level under the UNFCCC, but so far little progress has been in the negotiations. We performed a comparative study of climate change policies in major countries (the USA, the EU, Russia, China, and India) to see what kind of international institution would be agreeable to these countries and also to see why some countries were more willing than others to take action. The

study indicated that there is little possibility that a multilateral institution with ambitious emission-reduction targets for countries will be agreed on in the near future, and that agreements at the bilateral and regional levels are effective in facilitating climate change cooperation in areas such as technology transfer, REDD+ (the United Nations' enhanced program for Reducing Emissions from Deforestation and forest Degradation), and carbon markets. The study also developed four scenarios in which the multilateral arena could regain credibility and agreements could be reached.

5. The Eco-City System Research Section

This section pursues studies related to environmentally and economically sustainable cities, focusing on urban transportation systems, regional resource circulation, and energy systems. The target of the section is to develop an integrative urban environmental simulation system for regional carbon resources, waste circulation, local energy supply and demand networks, and urban and regional transportation and population migration patterns, and to integrate a combination of these systems.

(1) Integrative environmental policy and technology simulation system

After the establishment of an international research network among Japanese and Asian municipal governments, the potential environmental gains from a given set of technologies were determined to depend not only on the technologies themselves but also on local conditions such as energy structure and the carbon intensity of electricity. Development of clean energy and the promotion of recycling programs would contribute to GHG emissions reduction and improve local environments. Simulation of technologies will reveal the maximum potential for different management options as scientific references for planning and policy-making. Such simulations also predict land-use patterns. The simulation results will highlight the linkage between urban development and sustainable environmental resource management.

Figure 3 shows how research outcomes are used to develop an analytical model to investigate the potential environmental impacts of transferring circular environmental technologies, in this case plastics processing technology, from Japan to Shenyang in China. Shenyang is the capital city of Liaoning Province in northeastern China and has a total population of 8 million.

Japanese eco-towns have developed a number of plastics-recycling technologies, and waste plastics can be converted through mechanical recycling, chemical recycling, or energy-recovery processes into products that are substituted for virgin materials such as plastic resins, timbers, fossil fuels, and industrial feedstocks. As in these cases, the system boundaries in the assessment include waste transportation, processing, the impacts embodied in the substituted products, and the avoided impacts of waste disposal.

Fig. 3
Emission-reduction effects of transferring Japanese circular technologies to Shenyang, in China. Different effects with various ranges of social scenarios are quantified.

Potential of recycling non-PET plastics in treated outside of Shenyang

• Over 288 kt-CO_2e reduction and 120 kt-Ce fossil fuel saving against BaU (business as usual) could be realized by technology transfer only

• Additional 71 kt-CO_2e reduction and 35 kt-Ce saving could be achieved by reduction in carbon intensity in electricity and new recycling programs
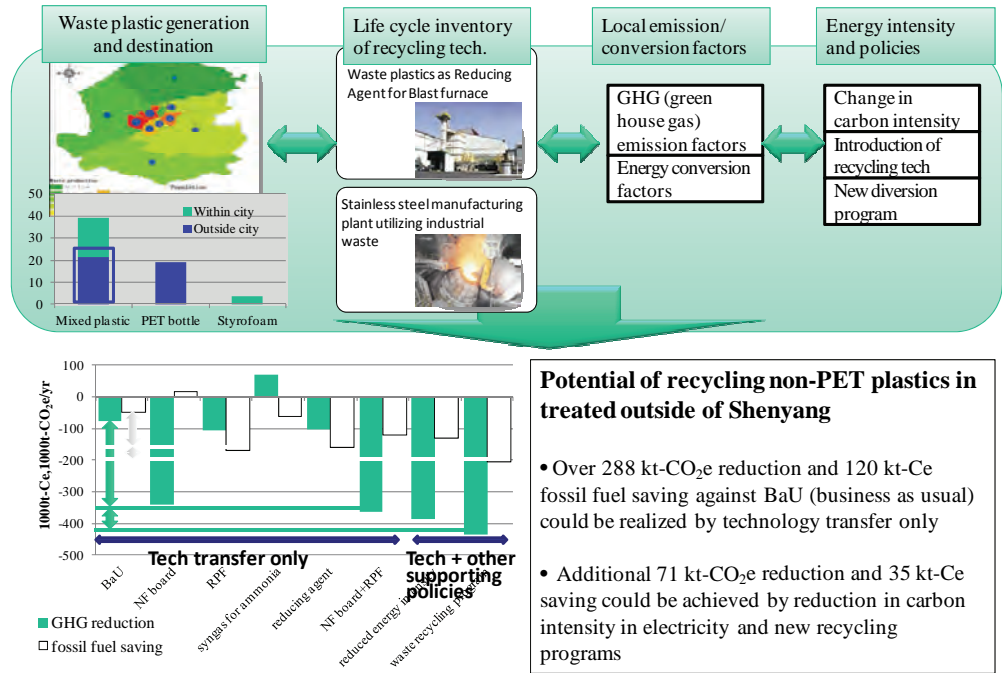
(2) Study of long-term CO_2-reduction strategies implemented by the transport sector towards a low-carbon society

As part of the transport-sector studies of the Japan Low Carbon Society 2050 Project, we used origin–destination data from the national road census to estimate CO_2 emissions from automobiles by municipality from 1980 to 2005. The motor vehicle CO_2 emissions map is available via the Environmental GIS Website of NIES (http://tenbou.nies.go.jp/gis/) (in Japanese). This map provides information on CO_2 emissions from passenger cars and freight vehicles. These estimations enabled us to analyze the regional characteristics and trends of automobile CO_2 emissions, trip frequencies, and average trip lengths. For example, a decrease in CO_2 emissions per capita from 1999 to 2005 was observed, especially in metropolitan regions. This study will help to establish national and local action plans for global warming countermeasures.

Center for Environmental Measurement and Analysis

a)

b)
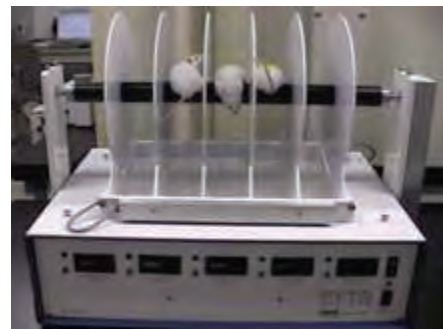
c)

a) Sampling points of bivalves for specimen banking;
b) rota-rod tests used for the examination of behavior during exposure of dipheylarsinic acid;
c) monitoring of phenological changes with a visible-near IR spectroradiometer.

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 new 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 (CRMs) and studying their analytical application for QA/QC. The Advanced Organic Analysis Section has been developing techniques for comprehensive analysis of organic pollutants, and 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. The Environmental Chemodynamics Section has been investigating the chemodynamics of natural and anthropogenic volatile organic compounds, as well as carbon cycles in the ocean. The Biological Imaging and Analysis Section has been pursuing the development of techniques for detecting and analyzing the *in vivo* responses of biological systems to various environmental factors. The Advanced Remote Sensing Section has been developing advanced techniques for remote sensing, such as lidar (laser radar), and the Environmental Information Analysis Section has been devising new methods of analyzing the large quantities of data gathered by using space- and ground-based remote-sensing techniques.

Following are brief accounts of some of the important results of our research in FY 2011.

Environmental Certified Reference Materials

Environmental CRMs are used to evaluate new analytical methods and to control the accuracy of pretreatment and instrumental analyses. We have been developing and distributing environmental and biological CRMs since 1980. Over 100 CRMs were distributed to researchers worldwide during FY 2011, and a new CRM (No. 29) for trace elements (e.g. Ba, Co, Cu, Fe, Mn, Mo, Mo, Sr, and Zn) in water hyacinth (*Eichhornia crassipes*) has been released (Fig. 1). Information on NIES CRMs can be found at http://www.nies.go.jp/labo/crm-e/ index.html.

Fig. 1 The water hyacinth for NIES CRM No. 29 was control-cultivated in the NIES Aquatron. From about 300 kg of raw material, 1054 bottles of CRM No. 29 (5 g of powder per bottle) were produced
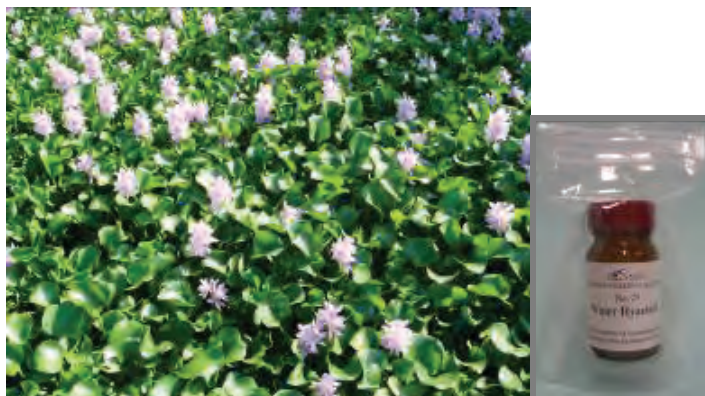
Status of bivalves and red stingray (*Dasyatis akajei)* livers for specimen banking at NIES unscathed by the 2011 Tohoku earthquake

It is important to have a resource of environmental specimens for investigating changes in contaminant exposure and accumulation over time. The environmental specimen banking (ESB) system at NIES started in 1980, and it became integrated into the ESTC (Environmental Specimen Time Capsule) program in 2003. Since 2003, the ESB facility has added 34 liquid nitrogen–vapor containers (–160 °C) with a total capacity of about 20.3 m^3, two freezer rooms (–60 °C) with a total capacity of 360 m^3, and 14 deep-freezers (–80 °C) with a total capacity of about 6 m^3. The ESB has been recognized as an important complement to environmental research and monitoring. For example, bivalves that have been archived from the beginning of our ESB system were utilized to help coastal environmental restoration program, to establish baseline concentrations of contaminants and heavy metals in the Japanese coastal environment, and to reveal both temporal and spatial variations in emerging pollutants. In addition to the bivalves, we have stored red stingray livers in our archive and have been expanding our liver banking activities since 2003. The standard operating procedure that we have developed helps to maintain the quality of the archived homogenized bivalves and liver samples. Moreover, our risk management plan has helped to prevent sample thawing as a result of incidents such as the catastrophic 2011 Tohoku earthquake. The cryogenically homogenized powdered environmental samples are stored in a cryogenic environment in liquid nitrogen–vapor containers at −160 °C and will be analyzed when new pollutants are identified in the future.

Global and selective detection of organohalogens in a sediment sample using neutral loss scan mode of GC×GC-MS/MS

We have been developing new methods for global and selective detection of organohalogens in environmental samples such as fly ash, sediments, and soil. One of the methods consists of comprehensive two-dimensional gas chromatography coupled with tandem mass spectrometry (GC×GC-MS/MS); a neutral loss scan (NLS) mode is used to selectively detect specific compounds. We measured a sediment sample (NIES CRM No. 20) by using a ^{35}Cl–NLS mode and a conventional scan mode; a two-dimensional total ion chromatogram (2D–TIC) was obtained with each measurement. A huge number of peaks and bands of complex compounds was observed in the chromatogram obtained with the conventional scan, but the many peaks from the sediment sample were successfully isolated with the ^{35}Cl–NLS.

The GC×GC-MS/MS delivered superior performance in the separation and selective detection of organochlorines. Figure 2 shows chromatograms obtained from a sediment extract by using the ^{35}Cl-NLS mode with conventional GC-MS/MS (top chromatogram) and with GC×GC-MS/MS (chromatogram second from top). There appear to be fewer peaks in the upper chromatogram than in the lower one. For example, on the TICs, the peak at 37.016 min in the chromatogram obtained by using GC-MS/MS (peak a) was separated into three

major peaks (peaks b, c, and d) with their own mass spectra when we used GC×GC-MS/MS. This shows that the separating power of conventional GC is insufficient to isolate each peak from a complex matrix in a crude sample, even when MS/MS is used for detection. Therefore, coupling of GC×GC and MS/MS can be an effective approach for complete global detection of organohalogens.

Fig. 2 Total ion chromatograms and mass spectra of a sediment sample (NIES CRM No. 20) measured in ^{35}Cl-NLS mode using conventional GC-MS/MS (top panel) and GC×GC-MS/MS (second panel from top). The other four images show the mass spectra of peaks a, b, c, and d.
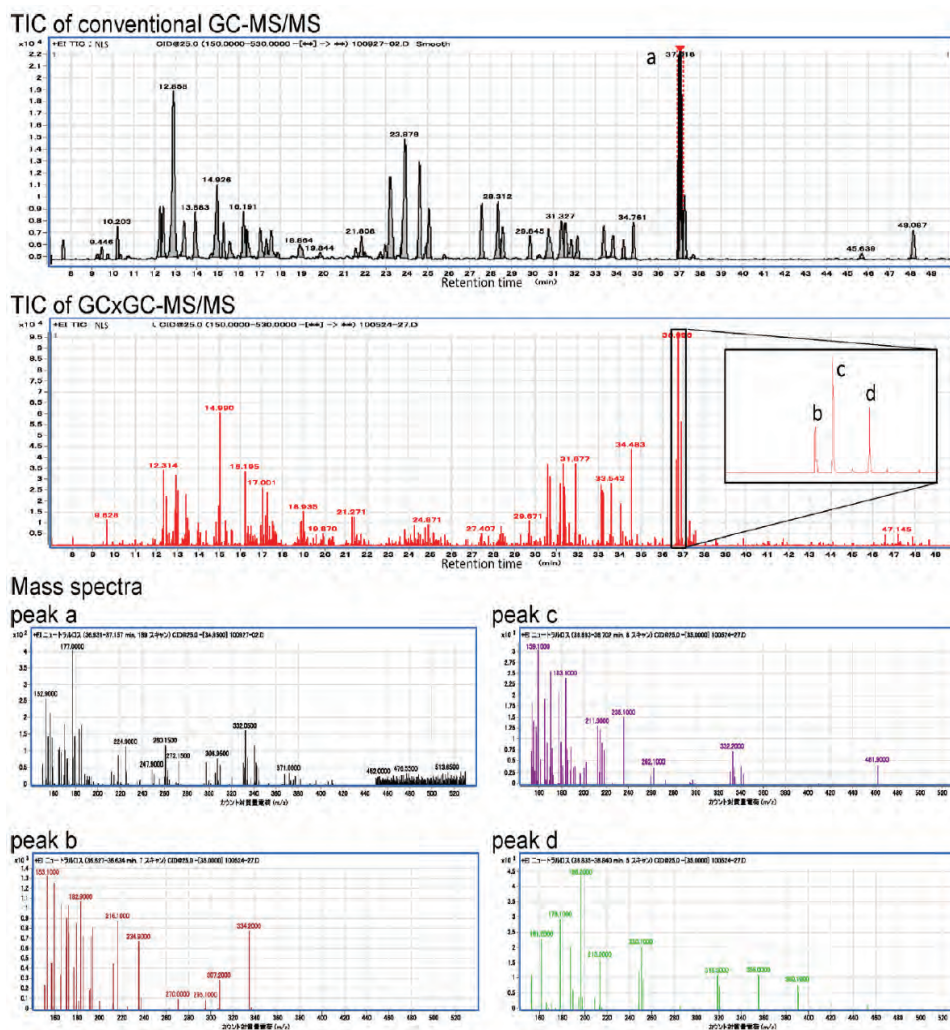
Diphenylarsinic acid administration to mice produces behavioral effects relevant to signs observed in people who ingested polluted well-water

After a number of people in one area of the city of Kamisu, in Ibaraki Prefecture, Japan, exhibited unusual health problems such as staggering and gait disturbance, pollution of the water in a local well with diphenylarsinic acid (DPAA) was found. We examined the effects of DPAA on various behaviors in mice. DPAA was administered to mice through free intake in drinking water for 27 weeks (subchronic exposure) or 57 weeks (chronic exposure), and behavior was examined during exposure. DPAA at 30 ppm significantly increased ambulatory

activity at 14, 16, 24 and 28 weeks compared with the control (Fig. 3a), and the response rate of the shuttle type discrete conditioned the avoidance response of mice. DPAA at 100 ppm reduced coordination ability on a fixed rod. Moreover, DPAA at 7.5 or 15 ppm reduced coordination on the rotating rod at 24, 26, 44 and 48 weeks (Fig. 3b). Chronic exposure to DPAA at 7.5 or 15 ppm had anti-anxiety-like effects in the elevated plus maze test, whereas subchronic exposure to DPAA at 100 ppm had anxiogenic-like effects. Neither subchronic nor chronic exposure to DPAA at 7.5 to 100 ppm affected learning ability or memory, as evaluated from passive avoidance response testing. Exposure of mice to DPAA at 15 or 30 ppm for 52 weeks did not alter the weight of the cerebrum or cerebellum or the amounts of the neuronal marker protein TUJ-1 or the astrocyte marker protein glial fibrillary acidic protein in the cerebellum. The behavioral effects observed in the mice, such as reduced coordination ability, seemed relevant to the signs observed in the patients from Kamisu.

Fig. 3 (a) Changes in ambulatory activity of mice that ingested tap water or DPAA solution at 7.5, 15, or 30 ppm for 57 weeks. (b) Changes in duration of stay on a rotating rod by mice in the rotarod test after 57 weeks' exposure to DPAA at 7.5 to 30 ppm. Tap water was available to control animals. Data are shown using medians and first and third quartiles.
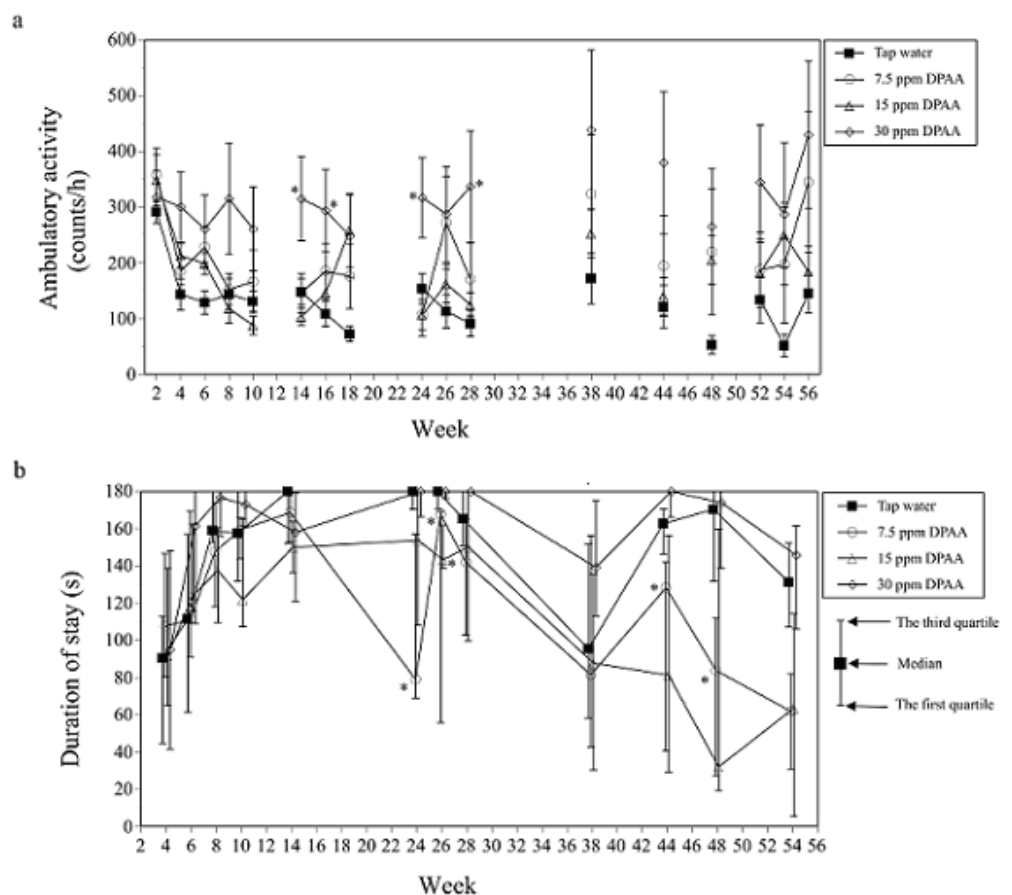
Advantages of visible-band spectral remote sensing at both the satellite and the near-surface scale for monitoring the seasonal dynamics of GPP in a Japanese larch forest

Remotely sensed vegetation indices such as the normalized difference vegetation index (NDVI) or enhanced vegetation index (EVI) have been used to scale up flux-based gross primary production (GPP) measurements. Recently, the use of visible-band (VIS) indices for estimating GPP has been proposed, and VIS_indices derived from digital cameras have been used for detecting phenological changes. To confirm the usefulness of remotely sensed VIS_indices for evaluating GPP in a Japanese larch forest, we investigated the relationships between flux-based GPP measurements and indices derived from both moderate resolution imaging spectroradiometer (MODIS) data and tower-mounted digital camera images. We evaluated the suitability of both traditional indices (NDVI and EVI) and VIS_indices [the green-red vegetation index (GRVI) and green ratio (GR)] at both the satellite and the near-surface scale for GPP estimation. We also used the MODIS data to evaluate the sensitivity of the indices to the effects of a severe forest disturbance. The results showed that VIS_indices had several advantages over the traditional indices: (1) seasonal variations in VIS_indices were more strongly correlated with GPP variations (Fig. 4); (2) the vegetation growing season could be easily discriminated from the winter dormant period because ground surface conditions affect VIS_indices less than they affect traditional indices; (3) the seasonal dynamics of vegetation could be determined at a satellite scale from the MODIS data and possibly even at a canopy scale from the digital camera images; and (4) inter-annual variations in VIS_indices were likely to be more sensitive to vegetation changes after a disturbance. These results demonstrate the utility of VIS_indices for estimating GPP at the satellite scale and possibly at the canopy scale. We suggest that multi-scale visible-band remote sensing could help us to understand ecosystems by improving the temporal and spatial resolutions of satellite data.

Fig. 4 Seasonal dynamics of daily gross primary production (GPP; left axis) and of MODIS-derived normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), green-red vegetation index (GRVI), and green ratio (GR) (right axes). Vertical dashed lines denote the start and end of each growing period, and arrows indicate periods of snow cover.
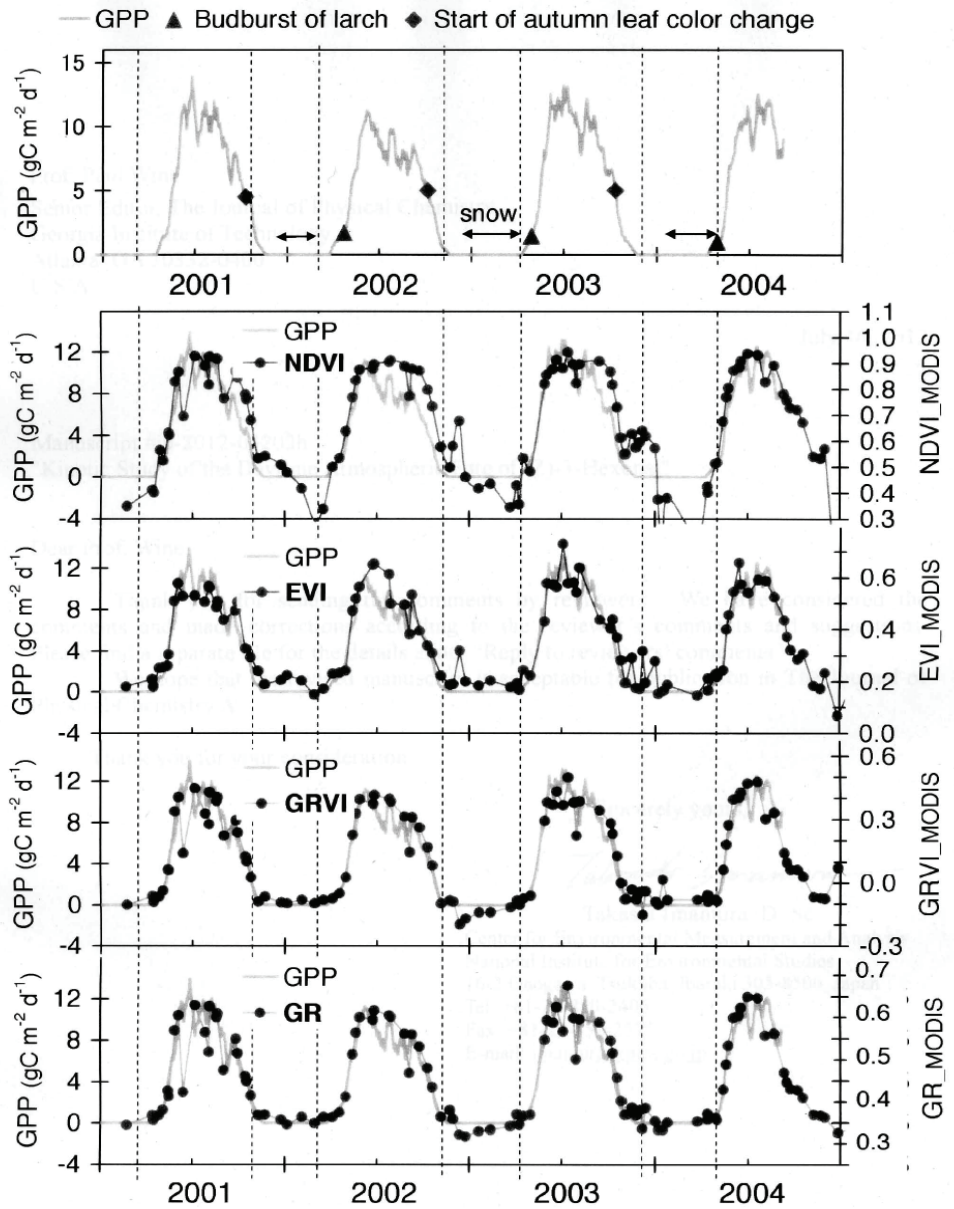
Environmental Information Department

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

The Environmental Information Department provides information technology (IT) support for research and related activities at NIES; runs public relations activities for NIES (including publishing NIES research reports); and performs miscellaneous other activities, including collecting and processing environmental information and disseminating it to the general public, 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.

a. Management and operation of computers and related systems

A new computer and network system started operation in March 2007. The UNIX-based computing environment consists of a supercomputer system and various subsystems, including a scalar-computing server, a front-end server, storage devices, and application servers. Our vector supercomputer (NEC SX-8R/128M16), 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. File transport was upgraded in March 2007. The network configuration was restructured, and large-scale file transport performance was improved at the same time. 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.

b. Use of IT to improve work efficiency at NIES

The Department gives IT support to the management sector 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 home page. In FY 2011, the Department supported:

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

c. Library service

As of March 2012, the NIES library held 58 976 books, 276 journals (including electronic resources), 122 268 microfiches, and various other technical reports and reference materials. These materials can be searched by using OPAC (Online Public Access Catalog) via the Intranet.

In addition to these materials, researchers at NIES can use abstracts and full-text articles through scientific and technical information databases such as ISI Web of Knowledge (including Web of Science, Medline, and Journal Citation Reports), JDreamII, G-Search, and CiNii.

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

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*.

a. Management of the NIES WWW

NIES began to provide public information on its research activities and results via the Internet (http://www.nies.go.jp/) in March 1996. The website was completely renewed and improved in accordance with the restructuring of NIES in April 2001 as an independent administrative institution. Because NIES started the third stage of its medium-term plan in April 2011, a newly designed website was prepared in accordance with the new organization and activities. The new site also provides information on NIES initiatives related to the Great East Japan Earthquake.

NIES News

Report of Special Research

Kankyogi

Annual Reports
(in English and Japanese)

b. Editing and publication of NIES reports

Reports on NIES research activities and results, 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

a. Collection, processing, and dissemination of environmental information

NIES is required to carry out "the collection, processing, and dissemination of environmental information" as one of its major tasks. The Department provides various kinds of environmental information to the public through websites, processes and manages environmental information databases, and provides environmental information via GIS (geographic information system).

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 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, domestic and global news updates, descriptions of key environmental technologies, information on policies and laws in environmental fields, environmental information via GIS, and other content helpful for environmental learning. The home page of the site was redesigned in March 2012 to offer improved usability.

Processing and management of environmental information databases
Various environmental data are needed for research, policy decisions, and policy enforcement. The Department compiles and processes air quality and water quality data collected by local government and reported to MOE. These processed data can be accessed through the database on the NIES website. Duplication and lending services are also available.
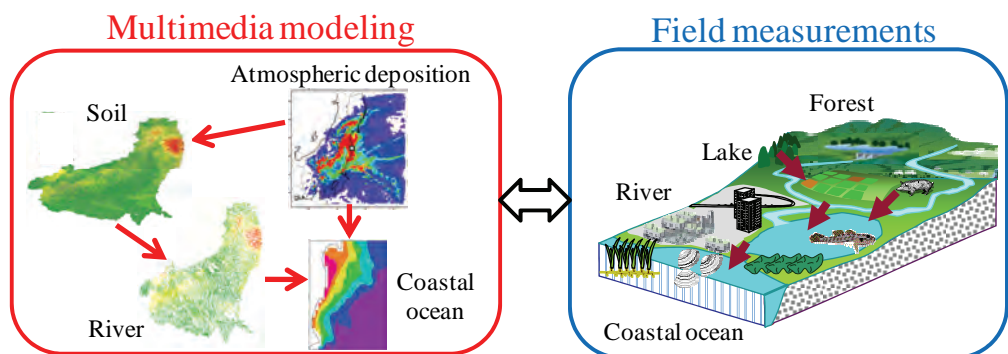
Provision of environmental information via GIS
The Department, with the cooperation of MOE, has been using GIS to develop an environmental data provision system. This system helps users to easily understand the status of the environment by showing data on environmental quality and other information on maps. The system has been publicly available through the Internet since September 2002 and was revised in March 2012.

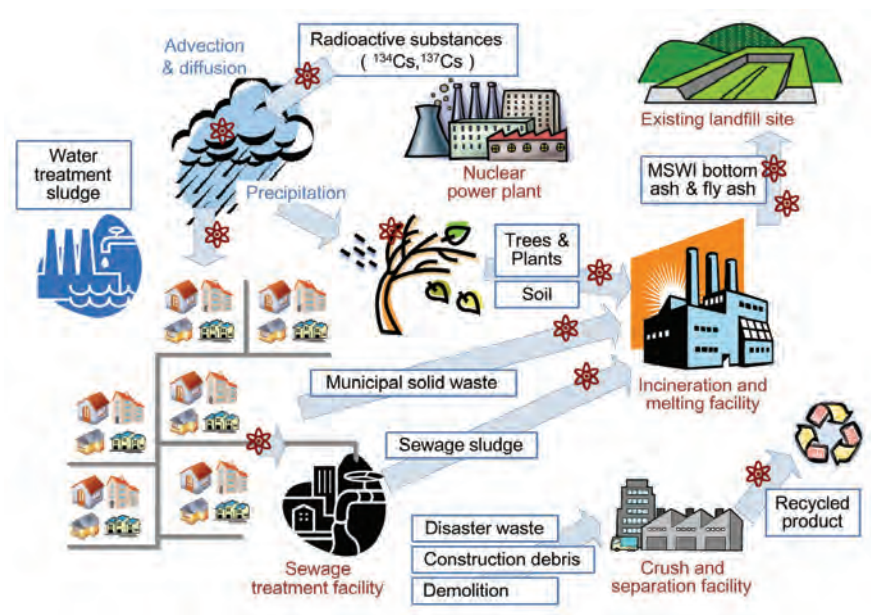***b. Tasks commissioned by the Ministry of the Environment***
In FY 2011, in tasks commissioned by MOE, GIS was used to evaluate the following dataset against quality standards:
- living environment data, covering noise, vibration, and offensive odors.

Radioactive Materials and Environmental Disaster Research

Multimedia modeling

Soil

Atmospheric deposition

River

Coastal ocean

Field measurements

Forest

Lake

River

Coastal ocean

Schematic diagram of multimedia environmental research

Advection & diffusion

Radioactive substances (^{134}Cs, ^{137}Cs)

Existing landfill site

Water treatment sludge

Precipitation

Nuclear power plant

MSWI bottom ash & fly ash

Trees & Plants

Soil

Municipal solid waste

Incineration and melting facility

Sewage sludge

Recycled product

Disaster waste

Construction debris

Demolition

Sewage treatment facility

Crush and separation facility

Flow of radioactive cesium

1. Study of dynamics of radioactive materials in multimedia environments

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

From this perspective, we performed a study of the dynamics of radioactive materials in multimedia environments on the basis of field measurements and multimedia fate modeling. We summarize the main results below.

(1) Radionuclides in atmospheric samples

We started monitoring radionuclides in surface air samples on 15 March 2011. The highest concentrations of radioiodine (^{131}I, ^{132}I, and ^{133}I) and radiocesium (^{134}Cs, ^{136}Cs, and ^{137}Cs) were observed at NIES on 15 and 16 March and from 20 to 22 March as a result of transport of the radioactive plume from the Fukushima Daiichi NPP. We obtained size distributions of radionuclides in the atmospheric samples in April 2011. Most radioiodine existed in gaseous form and was collected on a charcoal fiber filter; the rest was found in the fine-particle fractions. In contrast, most radiocesium was found in the coarse particles (>1 μm). These findings indicated that the chemical forms and transportation processes in the atmosphere differed between radioiodine and radiocesium.

(2) Runoff characteristics of radiocesium from a forested area

To examine the runoff characteristics of radiocesium from a forested area radioactively contaminated by the accident, we started hydrological observations immediately after the accident and sampled stream waters during rain events throughout the year in a small forested catchment (67.5 ha) on Mt. Tsukuba. We used a germanium semiconductor detector to measure the weight concentrations of ^{137}Cs in the solid phase extracted by centrifugal separation ($15,760 \times g$, 25 min) from the sampled stream waters. The suspended solids (SS) concentration and ignition loss (IL) were also measured for each sample. The annual runoff load of ^{137}Cs after the accident was estimated by multiplying the average weight concentration of ^{137}Cs in SS by the annual sediment load, as calculated by substituting automatically measured sequential flow rate data into a statistical equation that we developed using observed SS concentrations and flow rates to calculate the flux of SS load. The measured weight concentration of ^{137}Cs (0.84 ± 0.22 Bq/g, $n = 24$) in SS was not significantly correlated with the concentration of SS during rain runoff events. In contrast, there was a significant positive correlation between the measured weight concentration of ^{137}Cs and the IL in SS ($R = 0.67$, $P < 0.001$) (Fig. 1). This correlation suggests that quantitative evaluation of the contribution of particulate organic matter to ^{137}Cs runoff is needed. The estimated annual runoff load of ^{137}Cs per unit area was 0.04 kBq/m^2.

This value corresponds to only 0.3% of the estimated amount of ^{137}Cs deposited per unit area in the catchment. It is therefore likely that forested areas are currently contributing very little as a source of ^{137}Cs.

Fig. 1 Relationship between weight concentration of ^{137}Cs and ignition loss in suspended solids in stream water samples during rain runoff events.
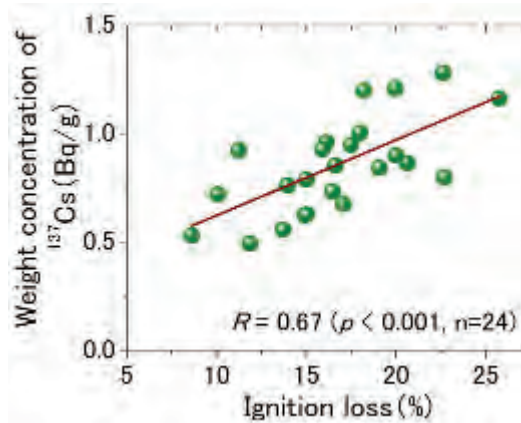
(3) Radionuclides in lake sediment samples

NIES has been collecting and analyzing Lake Kasumigaura sediment samples monthly for more than 30 years. The vertical distributions of radionuclides in sediment from Kasumigaura Station 9 (the deepest site), collected on 9 March (before the nuclear accident, core A) and 13 April (33 days after the accident, core B) are shown in Figure 2. Even before the accident, ^{137}Cs derived from nuclear weapons testing was present in sediment core A. However, after the accident, considerable amounts of ^{131}I and radiocesium were found in sediment core B down to 4 cm. The vertical profile gradually changed with time as a result of vertical mixing of the sediment and input from inflowing rivers.
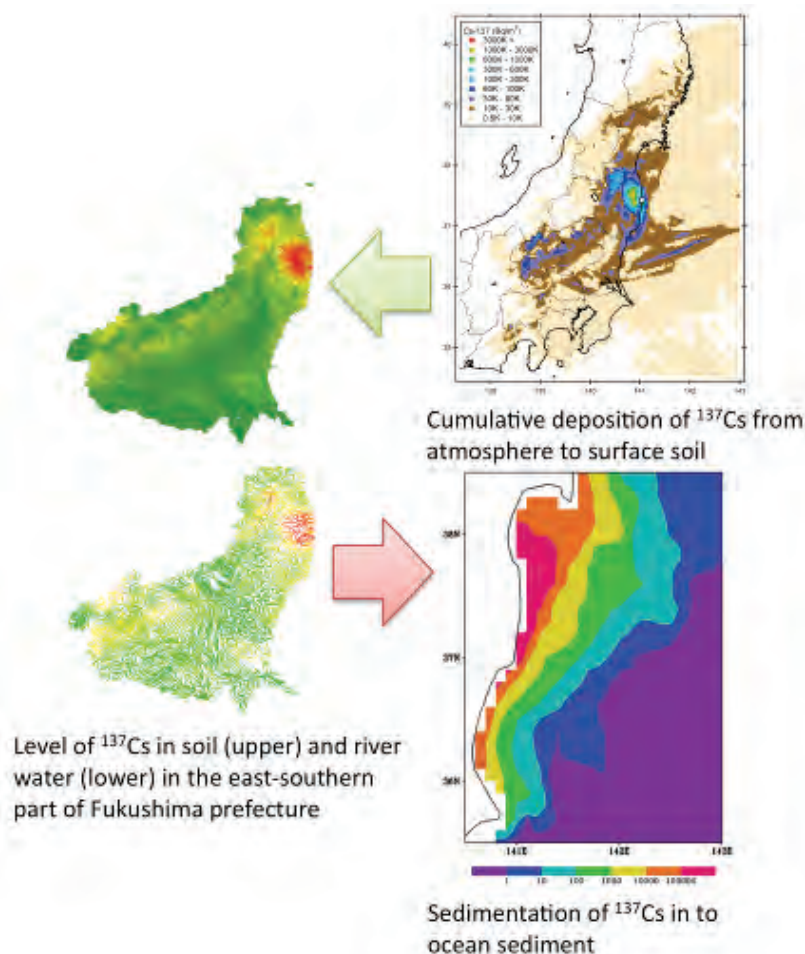
Fig. 2 Vertical distributions of radionuclides in Lake Kasumigaura sediment cores.
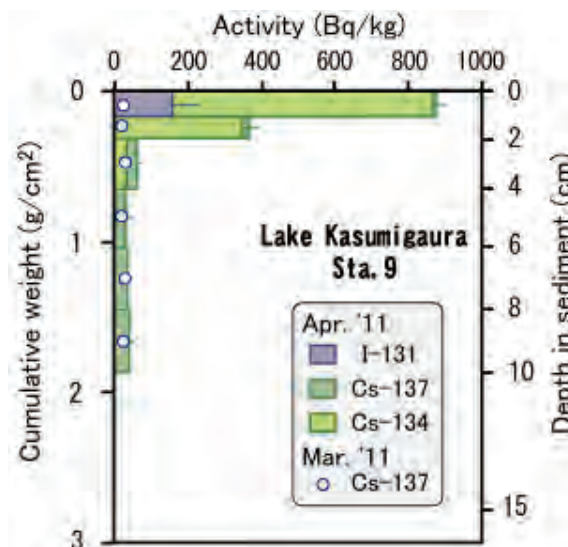
(4) Multimedia fate modeling

We have started developing a multimedia fate model of radioactive substances by coupling models for atmospheric, oceanic, and terrestrial environments. Development of the models for the atmosphere and ocean was based on an atmospheric transport and deposition model and a coastal sea model, respectively; both models were established at Center for Regional Environmental Research Development of the model for the terrestrial environment was based on the multimedia fate model G-CIEMS (Grid-Catchment Integrated Environmental Modeling System) established at our Center for Environmental Risk Research. By coupling the three models for atmospheric, oceanic, and terrestrial environments, we aimed to simulate the multimedia fate of radioactive substances in grid-based and appropriate geographic resolutions. This year we simulated the fate of radioactive cesium in the Abukuma River and surrounding river watersheds covering a major part of central and coastal Fukushima Prefecture, as a first trial of the coupled model scheme. The simulation period was set from just after the radiation accident to 2 to 20 years after the accident. Tentative results were obtained for temporal trends and spatial and geographic distributions; they revealed a slow trend in the fate of radioactive cesium over the entire simulation area. Figure 3 shows the results of our trial simulation of the fate of ^{137}Cs around Fukushima Prefecture, using the atmospheric transport and deposition model, terrestrial model, and ocean model combined.

Fig. 3 Trial simulation of the fate of ^{137}Cs around Fukushima Prefecture using combined atmospheric transport and deposition, terrestrial fate, and coastal sea models.

Cumulative deposition of ^{137}Cs from atmosphere to surface soil

Level of ^{137}Cs in soil (upper) and river water (lower) in the east-southern part of Fukushima prefecture

Sedimentation of ^{137}Cs in to ocean sediment

2. Establishment of technologies and systems for managing disasterwastes and 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 NPP accident left the terrible problem of solid waste contaminated by radioactive substances. We are performing various types of urgent research for central and local government into the appropriate management of these wastes so as to solve these problems as soon as possible.

Our research is reflected in notices 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) Analysis of incineration processes
We used a thermodynamic equilibrium model to predict the behavior of radioactive cesium during incineration of municipal solid waste (MSW) and biomass wastes. We also evaluated the efficiency of removal of radioactive cesium in exhaust-gas treatment systems such as bag filters and electric precipitators. Moreover, we performed experiments at a small scale and in a commercial incineration plant so as to gain a better understanding of the behavior of radioactive cesium. We obtained an abundance of fundamental knowledge from these studies.
Figure 4 is an example of the results of our thermodynamic equilibrium calculation. It shows the behavior of potassium in the combustion of MSW at various temperatures. We estimated the cesium behavior by replacing potassium with cesium. The main component of gas at temperatures over 800 °C was cesium chloride.

Fig. 4 Behavior of potassium in MSW at different incineration temperatures.
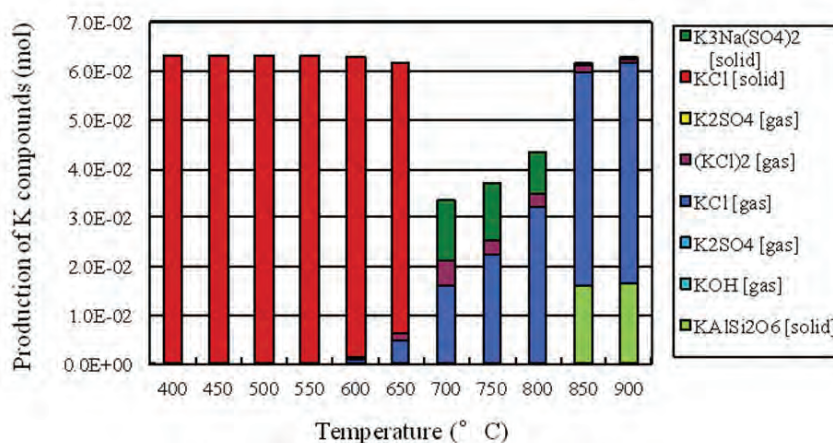
Table 1 Results of a survey of the efficiency of removal of radioactive cesium by commercial MSW incineration facilities.

Facility	Thermal process	Inlet conc. (Bq/m³)		Outlet conc. (Bq/m³)		Removal rate (%)		Fly ash collector
		^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	
A	Incineration	78	96	<0.008	<0.006	>99.99	>99.99	Bag filter
		98	126	0.008	<0.007	99.99	>99.99	
B	Incineration	33	42	0.2	0.2	99.39	99.52	Electric precipitator
		43	57	0.2	0.2	99.53	99.65	
C	Incineration	58	70	<0.054	<0.053	>99.91	>99.92	Bag filter
D	Incineration	58	76	<0.1	<0.1	>99.83	>99.87	Bag filter
	Electric melting	677	844	<0.1	<0.1	>99.99	>99.99	

Table 1 shows the results of a survey of four commercial MSW incineration facilities in terms of their efficiency of removal of radioactive cesium by bag filters and electric precipitators. During the process of rapid gas cooling followed by bag filters, vaporized radioactive cesium compounds are solidified or adsorbed on the surface of fly ash particles. The particles can be removed by bag filters; thus the removal efficiency exceeded 99.9%.

(2) Analysis of landfill processes
We obtained a large amount of useful knowledge about appropriate landfill operations by conducting field surveys and experiments. (See points 1 to 4 below.) We also conducted observational surveys to enable us to give technical advice to central and local governments on how to dispose of radioactively contaminated fly ash.

1) Leachability of radioactive cesium
We performed different types of leaching tests including JIS K0058-1 stirring test, a sequential extraction test, etc, using various samples to determine the leachability of radioactive cesium. Table 2 shows that in JIS K0058-1 stirring test the leachability of radioactive cesium from MSW incineration fly ash was much higher than that from MSW incineration bottom ash.

Table 2 Leachabilities of radioactive cesium from various types of waste samples by JIS K0058-1 stirring test.

Facility and Sample		$^{134}Cs + {}^{137}Cs$			pH	EC (mS/m)
		Total in solid (Bq/kg)	Leachate (Bq/L)	Leached ratio (%)		
A	Raw flyash	10140	903	89.1	11.4	2510
	Treated flyash	8170	705	86.3	10.2	1780
B	Bottom ash	2450	<20	<8.2	12.0	401
	Raw flyash	32400	2760	85.2	12.2	3830
	Treated flyash		270	13.1	12.4	3270
	(Crush <30 mm)	20600	1590	77.2	12.4	3240
	(Crush <2 mm)		1630	79.1	12.4	3240
C	Bottom ash	371	<14	<37	11.9	385
	Raw flyash	3480	223	64.1	12.3	3850
	Treated flyash	1520	101	66.4	12.5	2050
D	Bottom ash	344	<15	<44	12.5	802
	Raw flyash	11000	875	79.5	12.2	6620
	Treated flyash	7510	662	88.1	12.1	4700
E	Bottom ash	212	<14	<64	11.9	349
	Raw flyash	2400	201	83.8	12.1	5570
	Treated flyash	1520	102	67.1	11.8	2600
F	Slag	280	<15	<52	8.2	3.9
M	Bottom ash	15200	84.7	5.6	12.5	976

2) Sorption of radioactive cesium

In landfill sites, soil sorption of radioactive cesium can work to retard transport of cesium in the soil layer. We conducted sorption tests using six soil samples and evaluated the cesium distribution coefficients. Figure 5 shows that powdered mordenite had a large cesium sorption capacity.

Fig. 5 Distribution coefficients of radioactive cesium in several soil materials.
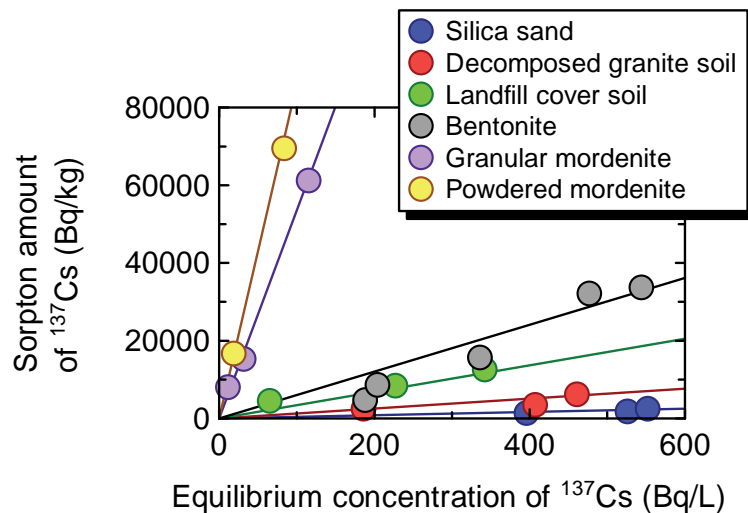

3) Behavior of radioactive cesium in a landfill site

We modeled and calculated the behavior of radioactive cesium in a landfill site by using the ratios of leaching from MSW incineration ash (see Table 2) and the

distribution coefficients in soils (see Figure 5). The concentration of radioactive cesium in landfill leachate was calculated on the basis of the amount of rainwater infiltration.

Figure 6 is the result of a calculation using an infiltration rate of 10 mm/year. In this calculation, as a safety factor, we assumed that the infiltration rate would increase 5 times (to 50 mm/year) after 50 years as a result of deterioration in the impermeable cover layer. We can use such simulations to estimate the fate of radioactive cesium in landfill leachate.

Fig. 6 Concentration change of ^{137}Cs in leachate. The infiltration rate was assumed to increase from 10 to 50 mm/year after 50 years.
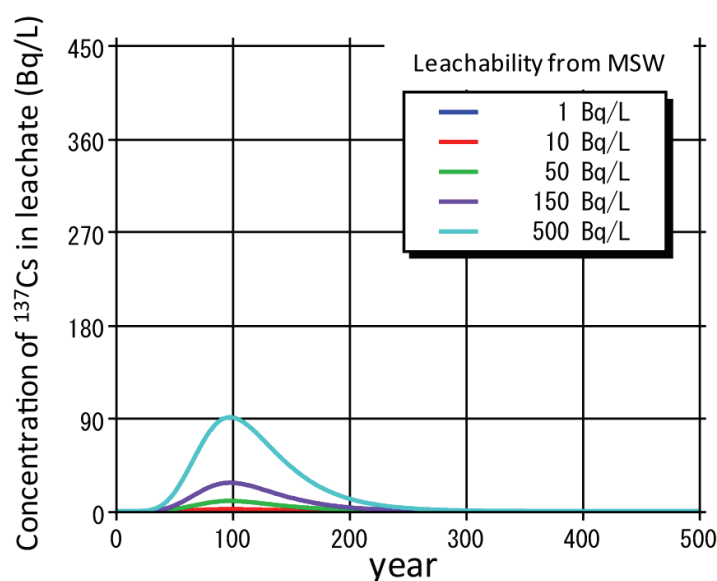
4) Evaluation of leachate treatment systems

We conducted experiments and an on-site survey of leachate treatment systems in terms of the leaching of radioactive cesium from landfilled waste because of rain. We evaluated treatments using zeolite and a reverse osmosis (RO) membrane.

Our research indicated that radioactive cesium adsorption and removal by using zeolite was effective. However, this is not suitable as a permanent system because the zeolite must be exchanged frequently.

Cesium removal efficiency was very high (97% to 99%) in the treatment system that used a double RO membrane system. The problem is that cesium is concentrated in wastewater from such a system. We therefore need to consider how to manage wastewater containing concentrated cesium.

(3) Standardization of a method for analyzing radionuclides in wastes

There is not enough knowledge about the proper evaluation of wastes contaminated by radioactive substances. We launched a study group consisting of members from the public and private sectors, and we have now compiled a manual for the analysis of radioactively contaminated wastes.

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