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NIES Annual Report 2013

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National Institute for Environmental Studies
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Foreword

This annual report is the official record of activities at the National Institute for Environmental Studies (NIES) in Fiscal Year (FY) 2012 (April 2012 to March 2013). FY 2012 marked the second year of the third NIES five-year plan (FY 2011–2015). It was also the second year in which our institute has been engaged in Research on Disaster Environment, which was initially undertaken in the aftermath of the Great East Japan Earthquake. In this, NIES Annual Report 2012, we will take the opportunity to report on the research being undertaken at NIES as part of this five-year plan as well as the outcomes of Research on Disaster Environment.

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

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

The third aspect involves the maintenance of medium- to long-term initiatives in step with the sustainment and furtherance of environmental research. This includes maintaining the equipment and facilities needed for initiatives such as global environmental monitoring - including that by satellites - and those initiatives that use ground-based systems, commercial airlines, and shipping to monitor and analyze the global carbon cycle. Other examples of such initiatives include the maintenance of a GHG emissions inventory; the storage and provision of environmental specimens; the maintenance of reference laboratory functions; and the creation and updating of many kinds of environmental databases.

Another important topic at NIES is the advancement of research using the NIES Supercomputer. Also, the Japan Environment and Children's Study (JECS) is continuing in a satisfactory manner.

Research on Disaster Environment, undertaken in the aftermath of the Great East Japan Earthquake, comprises the fourth aspect of our strategy. To actively and effectively tackle this new undertaking, it was highlighted in March 2013 in an update of the third NIES five-year plan. NIES Fukushima Headquarters (provisional name) is currently cooperating in the setting up of the planned Fukushima Prefecture Environmental Creation Center (provisional name) through which we intended to increase our presence and on-the-ground activities in the area.

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

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

SUMI, Akimasa
President
September 2013

Contents

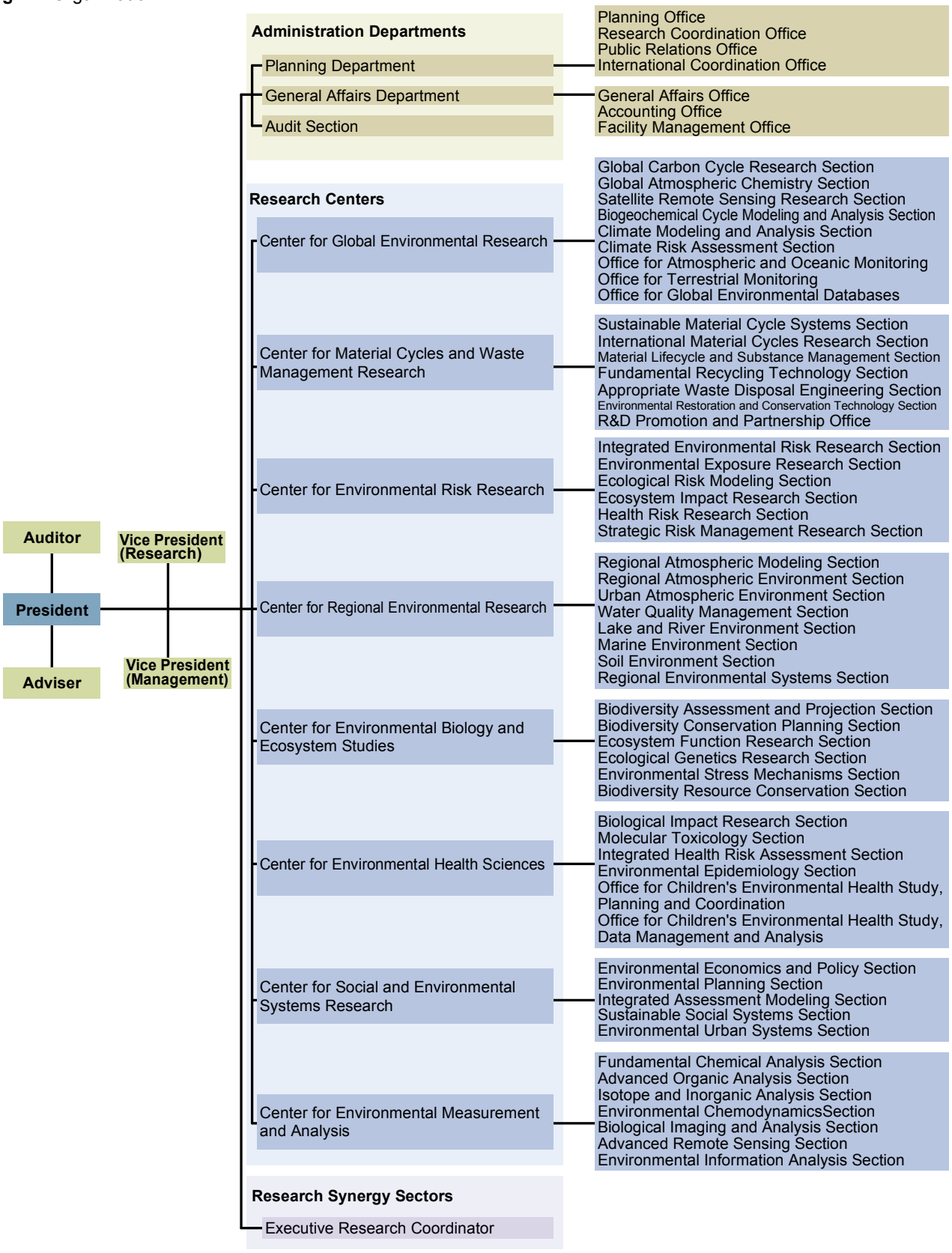
During the 1950s and 1960s, Japan experienced serious environmental pollution problems accompanying rapid economic growth. The Environment Agency was established in 1971 as part of the Japanese government to develop measures to counteract serious problems associated with environmental pollution, such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

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

January 2001 saw the transition of the Environment Agency into the Ministry of the Environment as part of structural changes within the Japanese government, and the establishment of a Waste Management Research Division at NIES. April of that year also marked the establishment of NIES as an Incorporated Administrative Agency, giving it a degree of independence from the national government. The change in the administrative status of the institute 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, 10 Designated Research Programs are specified, and the research that is currently being advanced under these programs emphasizes the tying-together of the different fields active at NIES. 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 on Hateruma Island and at Cape Ochi-ishi, to further these research activities. 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, and with an emphasis on those in Asia.

Fig. 1 Organization



In the aftermath of the Great East Japan Earthquake of March 11 2011, NIES has provided its 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-stricken area. Also, NIES has made diligent efforts to promote research aimed at understanding and elucidating the status - and clarifying the movement - of radioactive substances in the environment.

As of April 1 2013, the total number of NIES regular permanent staff was 257. There were also 490 non-permanent researchers (Table 1; Figs. 2 to 4). The total budget for FY 2012 was 16,039 million yen (Table 2).

Table 1 Numbers of permanent staff.

Administration Departments	53	20.6%
Research Centers	198	77.0%
Research Synergy Sectors	1	0.4%
Executive	5	2.0%
Total	257	100%

(As of April 1, 2013)

Table 2 Budget for the third five-year plan.

(Unit: million yen)

	Category	2011–2015 Budget (5 years)	Fiscal Year 2012 Budget
Revenue	Grants for Operating Costs	68,519	12,111
	Subsidies for Facilities	1,540	263
	Commissioned Work	18,057	3,611
	Other	147	54
	Total	88,264	16,039
Expenditure	Project Costs	50,918	8,653
	Facility Improvements	1,540	263
	Expenses for Commissioned Work	18,057	3,611
	Personnel Expenses	15,516	3,026
	General Administrative Expenses	2,232	486
	Total	88,264	16,039

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

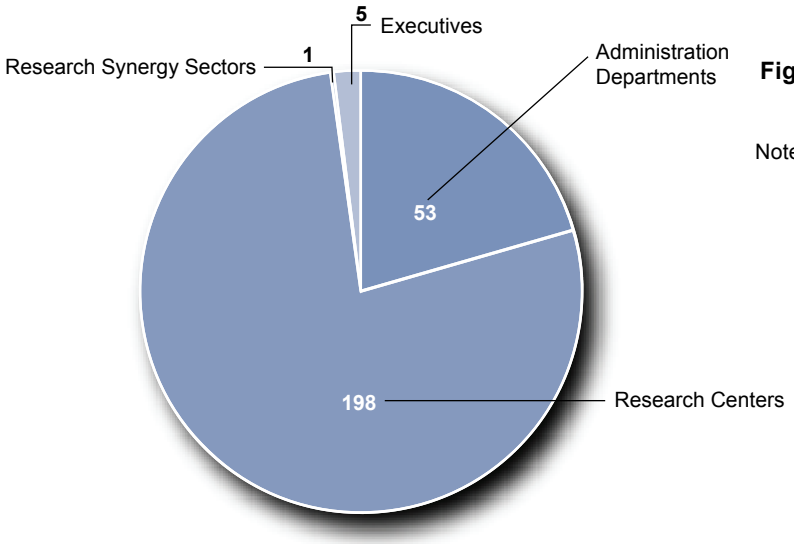


Fig. 2 Number of Permanent Staff
257

Notes: Data is as of April 1, 2013

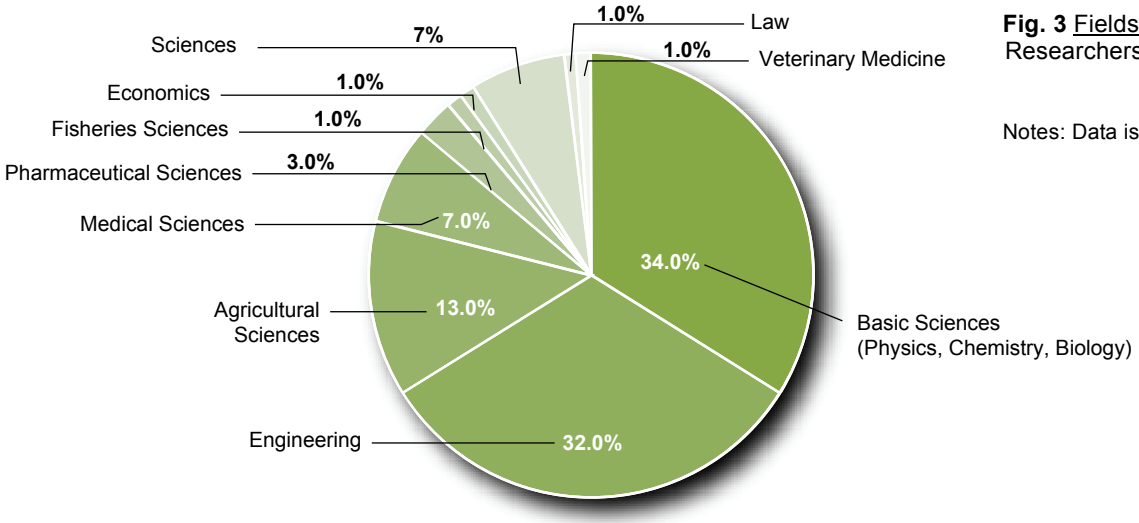
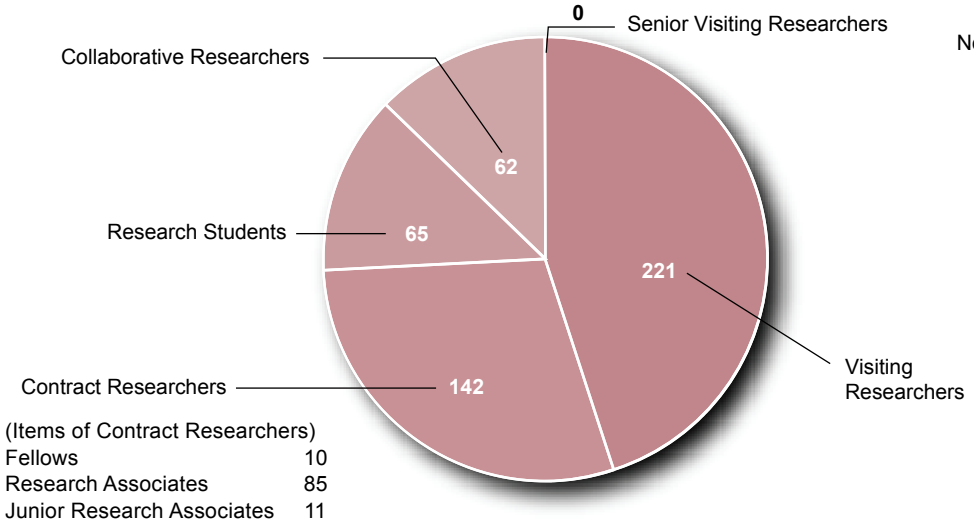


Fig. 3 Fields of Expertise
Researchers holding doctorates
95.8%

Notes: Data is as of April 1, 2013



(Items of Contract Researchers)

Fellows	10
Research Associates	85
Junior Research Associates	11
Research Assistants	36

Fig. 4 Number of Visiting Researchers, etc
490

Notes: As of April 1, 2013 (However, the figures for Visiting Researchers, Research Students, Collaborative Researchers, and Senior Visiting Researchers reflect the total number accepted in FY2012).

Center for Global Environmental Research

Ground-based GHG monitoring station established at Hateruma in 1992.
Ambient CO_2 concentrations—with a 10% increase—have been observed at the station in the 20 years since it opened.

Outline of the Center for Global Environmental Research (CGER)

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

Considering the scale and seriousness of the predicted impacts, it is vital 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 today's environmental conditions and their variations, CGER performs future projections and impact risk assessments of global environmental change. It also conducts research into measures to preserve the global environment. In cooperation with other research centers, CGER implements climate change research with a special emphasis on observing and clarifying global variations in GHG concentrations in the atmosphere. It also aims to elucidate 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 5-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 2012.

Integration of flux estimations obtained by using top-down and bottom-up methods

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. From the GOSAT project, we obtained 64 regional CO_2 flux maps. To compare these results with those of terrestrial flux modeling, we adjusted the model calculation regions to those of 64 inverse calculation regions and then compared the CO_2 flux of each terrestrial region.

This year, we started more precise experiments in Siberia and Hokkaido. We tried to develop a high-resolution atmospheric model to estimate local CO_2 flux and apply it to Siberia and Hokkaido. In Hokkaido, we set up three CO_2 measurement systems to collect data simultaneously along the major wind direction (west to east). We found that the CO_2 concentration was lower downstream than upstream, because the

terrestrial biosphere took CO_2 from the atmosphere in the daytime. To measure uptake speed, we measured the vertical profile of CO_2 by using a recently developed CO_2 sonde (Fig. 1). We attempted to compare the GOSAT data with our data, but unfortunately cloud cover in summer in the measurement areas made GOSAT measurement difficult. Comparison of a terrestrial flux model simulation and our top-down approach for estimating CO_2 local flux revealed that the estimates matched roughly. We have now developed a high-resolution forward atmospheric model to simulate CO_2 concentration and will use it to create an inverse modeling technique in the future. In addition, we used the ^{14}C of CO_2 in this project to determine CO_2 origin and the contribution of various fluxes, such as those from soil, plant, and anthropogenic sources.

In Siberia, we measured many vertical profiles of CO_2 from airplanes to estimate CO_2 flux over the west Siberia region. Inverse model calculation for this region will be done in the near future. To integrate the data from our various observation points, we are summarizing the data and have initiated a new database system that will help to analyze global source and sink distributions and temporal variability in GHG concentrations.

Fig. 1 The CO_2 sonde, which can reach an altituted of up to 10 km.

Dependence of geographic pattern of temperature change on future emission scenarios

Research related to the impacts of, and adaptation to, climate change requires the results of climate modeling based on a wide range of socioeconomic and emission scenarios. Although atmosphere–ocean general circulation models (AOGCMs) are the most promising for simulating future climates, the use of AOGCMs to simulate future climates for a variety of emission scenarios requires very large computer resources.

Pattern scaling is a highly useful method for generating climate simulations for a wide range of emission scenarios. The basic assumption of pattern scaling is that

the spatial pattern of change in a climate variable per 1 K increase in global mean surface air temperature (scaling pattern) is common to all emission scenarios. By using the MIROC5 AOGCM developed by a Japanese research group, we recently investigated the scenario dependency (SD) of temperature scaling patterns to validate the basic assumption of the pattern-scaling approach. We focused on the effects of aerosols, sea ice, and Atlantic meridional overturning circulation (AMOC).

We found significant dependencies of the scaling pattern on emission scenarios at middle and high latitudes of the Northern Hemisphere over parts of East Asia, North America, and Europe (Fig. 2). Impact researchers should take note of these dependencies, which could substantially affect their results. The mid-latitude dependence is caused by the SD of the sulfate aerosol scaling pattern, and the high-latitude dependence is caused mainly by the nonlinear responses of sea ice and AMOC.

Because the differences in global mean surface air temperature (SAT) changes between RCP8.5 (Representative Concentration Pathway 8.5, one of a number of GHG concentration trajectories adopted by the Intergovernmental Panel on Climate Change) and RCP4.5 were smaller than those between RCP8.5 and RCP2.6, the difference in temperature scaling pattern between RCP8.5 and RCP4.5 tended to be smaller than that between RCP8.5 and RCP2.6 overall. Thus, when pattern scaling is applied to an emission scenario, it is better to minimize the SD by using the RCP that projects global mean SAT changes similar to those projected by the target emission scenario.

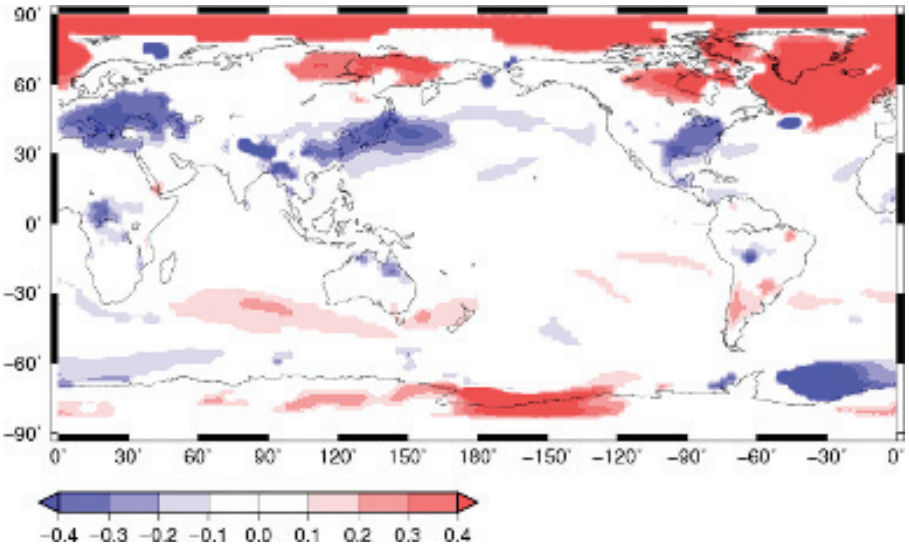


Fig. 2 Differences in scaling patterns of annual surface air temperature between two GHC concentration scenarios, namely RCP8.5 and RCP2.6. Colored regions are statistically significant at the α = 0.05 level (F-test).

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

The aim of this study is to provide scientific knowledge from the perspectives of modeling and analysis, scenario development, and negotiation processes in order to achieve a low-carbon society at the local, national, regional, and global levels. To achieve this aim, this study consists of 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 the world; and (3) study of international institutions and negotiation processes for the development of a low-carbon society.

In sub-theme 1, we summarized the narrative scenario for a low carbon society in Asia as "10 actions." This analysis was performed by a team comprising internal NIES researchers and external researchers. The actions consist of transportation, material use, energy supply and demand, agriculture and land use, and trans-boundary options such as a carbon tax and improvement of governance. We applied the scenario approach to the Iskandar area of Malaysia, and a report on the study, titled "12 Actions Towards a Low Carbon Future," was released at a side event at the United Nations COP (Conference of the Parties) 18, in 2012. The 12 actions for Iskandar cover green economy, green community, and green environment. Under the reference scenario, GHG emissions in this area would increase from 10.5 Mt CO_2 in 2005 to 30.2 Mt CO_2 in 2025, but introducing the 12 actions was estimated to reduce GHG emissions in 2025 to 18.3 Mt CO_2.

In sub-theme 2, an integrated assessment model that we developed, namely the AIM (Asia-Pacific Integrated Model), was applied to assess various international climate targets. For example, AIM/Enduse [Global] was applied to assess the technological feasibility and economic viability of the 2050 global GHG emission reduction target required to stabilize radiative forcing at 2.6 W/m^2. The simulation result showed that the emission reduction target is technologically feasible, but the cost of achieving the target would become very high if nuclear and carbon capture and storage (CCS) options were to be limited. The main reason for the high cost is that additional investment in expensive technologies would be required to compensate for emission increases in the steel, cement, and power-generation sectors in the absence of CCS. On the other hand, if materials-related efficiency improvement measures, such as material substitution, efficient use of materials, and recycling, were implemented, then the cost of achieving the emission reduction target would be substantially reduced.

The main issue in sub-theme 3 was the post-2012 international framework for climate change mitigation. In this study we conducted an online questionnaire survey on a plausible international framework for the post-2020 period; this framework is to be agreed to under the Durban Platform. The results of the survey revealed several insights, including the following: (1) although the Durban

Platform aims to agree on a framework with legal force, about 40% of all respondents answered that their countries would prefer a COP decision or a political declaration rather than a protocol; (2) a majority of respondents said that their countries would prefer legally binding emission targets over voluntary targets; and (3) countries would find the framework most useful (and thus would achieve the greatest satisfaction) if it included a financial mechanism involving a wide variety of financial resources including private funds; this third result was consistent for both Annex I and non-Annex I countries.

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 14 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.

UV-B observed at four sites in Japan show clear seasonal variations, with a maximum in July and a minimum in January. The winter values in northern Japan (at Rikubetsu and Ochi-ishi) are nearly zero owing to the long path-length of solar radiation. Observations were started at Hedo Station, on the main island of Okinawa, in August 2012. The UV-B values there are similar to those observed at Hateruma (Fig. 3). No obvious UV-B trends have been found at any of the monitoring sites.

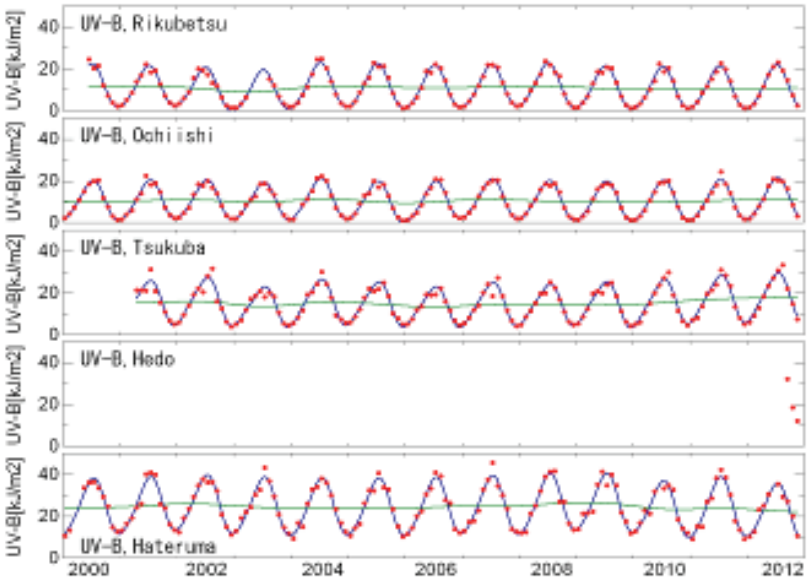


Fig. 3 Time-series of UV-B observed at Rikubetsu, Cape Ochi-ishi, Tsukuba, Hedo, and Hateruma. Red dots are observation data; blue solid lines are fitted curves; and green lines are long-term trends. Observations at Hedo did not start until August 2012.

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 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 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 beginning of the growing season were clearly observed and were dependent on the rate of spring snowmelt and the ecosystem type.

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

Global Environmental Databases

Since the early 2000s the Office for the Global Environmental Database at CGER has been constructing and providing databases on several topics related to Earth's global environment. There are five major tasks in this project: (1) construct, maintain, and renew the database servers that provide our databases; (2) construct databases and provide the public or researchers with data gathered by the Earth environmental monitoring project at our institute; (3) construct databases on social environmental sciences related to global warming; (4) develop convenient tools to analyze Earth environment datasets; and (5) achieve international cooperation on database-related issues. Currently, we are providing the following databases from our server at NIES: A) databases on global warming related to GHG observations (7 databases), carbon sources or sinks (8), material flows (10), and the effects and measurement of global warming (3); B) databases on the atmospheric environment related to the stratospheric ozone layer or UV (6 databases), air pollution or acid rain (10), or trajectory analysis (1); C) databases on marine or freshwater environments (8); D) databases on biology (3); E) databases on satellite remote-sensing or geographic information systems (7); F) databases on international cooperation (7); And G) databases on other topics (6). In March 2013, the home page of the Global Environmental Database was revised (Fig. 4).

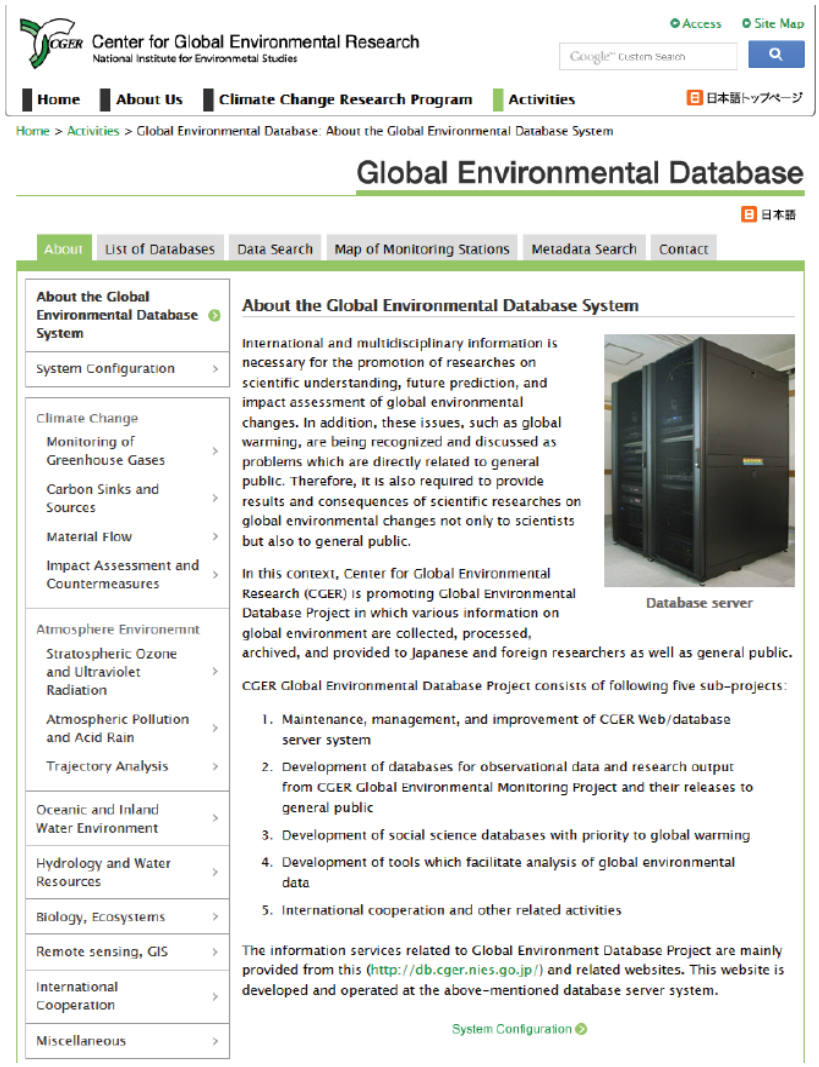


Fig. 4 Revised home page of the Global Environmental Database (http://db.cger.nies.go.jp/)

Greenhouse Gas Inventory Office of Japan

The Greenhouse Gas Inventory Office of Japan (GIO) was established in July 2002 at CGER to perform various tasks and projects, including the compilation of a national GHG inventory, which is GIO's primary mission, and others as listed below.

Tasks and projects within the country are: (1) annually preparing Japan's national GHG inventory, (2) providing support for the technical review of the national GHG inventory of Japan, and (3) providing support for inventory-related policies and actions (e.g. by supporting the Committee on Methods for Estimating GHG Emissions).

The total GHG emission in FY 2011 (excluding the Land Use, Land Use Change, and Forestry Sector) was 1308 million tonnes (in CO_2 equivalent). This was an increase of 3.7% compared with emissions in the base year under the Kyoto Protocol. Compared with emissions in FY 2010 this was an increase of 4.0% and

was due to such factors as the expansion of thermal power generation.

International tasks and projects include: (1) convening the Workshop on Greenhouse Gas Inventories in Asia (WGIA), (2) international cooperation for improving national GHG inventories, and (3) contributing to the technical review of national GHG inventories of other Parties as reviewers for the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol.

Since 2003, the Ministry of the Environment of Japan and the GIO have organized the WGIA, which aims to help Asian countries to develop and improve their GHG inventories in cooperation with participating countries such as Cambodia, China, India, Indonesia, Japan, the Republic of Korea, Lao PDR, Malaysia, Mongolia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. The tenth WGIA was held from 10 to 12 July 2012 in Hanoi, Vietnam and was attended by 130 experts; it was the largest-scale Workshop yet.

NIES GOSAT project

We continued processing GOSAT data at the NIES GOSAT Data Handling Facility, and we continued online distribution of GOSAT data products to researchers and the general public via the GOSAT User Interface Gateway (GUIG, http://data.gosat.nies.go.jp/). In addition to the data products already made available to users, we newly disseminated the following data items: X_{CO2} and X_{CH4} column concentrations, which are the Level 2 data products (version 02.xx) of the TANSO-FTS (Thermal And Near-infrared Sensor for carbon Observation – Fourier Transform Spectrometer) SWIR (Short Wavelength Infra-Red) band for the entire past observation period; and a TANSO-CAI (Cloud and Aerosol Imager) Level 3 NDVI (Normalized Difference Vegetation Index) product open to general users. Also, GOSAT Level 4A (regional monthly CO_2 fluxes with their uncertainties, Fig. 5) and Level 4B (model-simulated three-dimensional distributions of CO_2 concentrations) data products for the period from June 2009 to May 2010 have been released. At this stage, all of the planned GOSAT standard data products, except for FTS TIR (Thermal Infra-Red) Level 3, are available to general users.

The GOSAT Project website and GUIG have been maintained, and we have updated important information on GOSAT data products for GOSAT data users. Three issues of the GOSAT Newsletter, in Japanese and in English, have been published online on the GOSAT website.

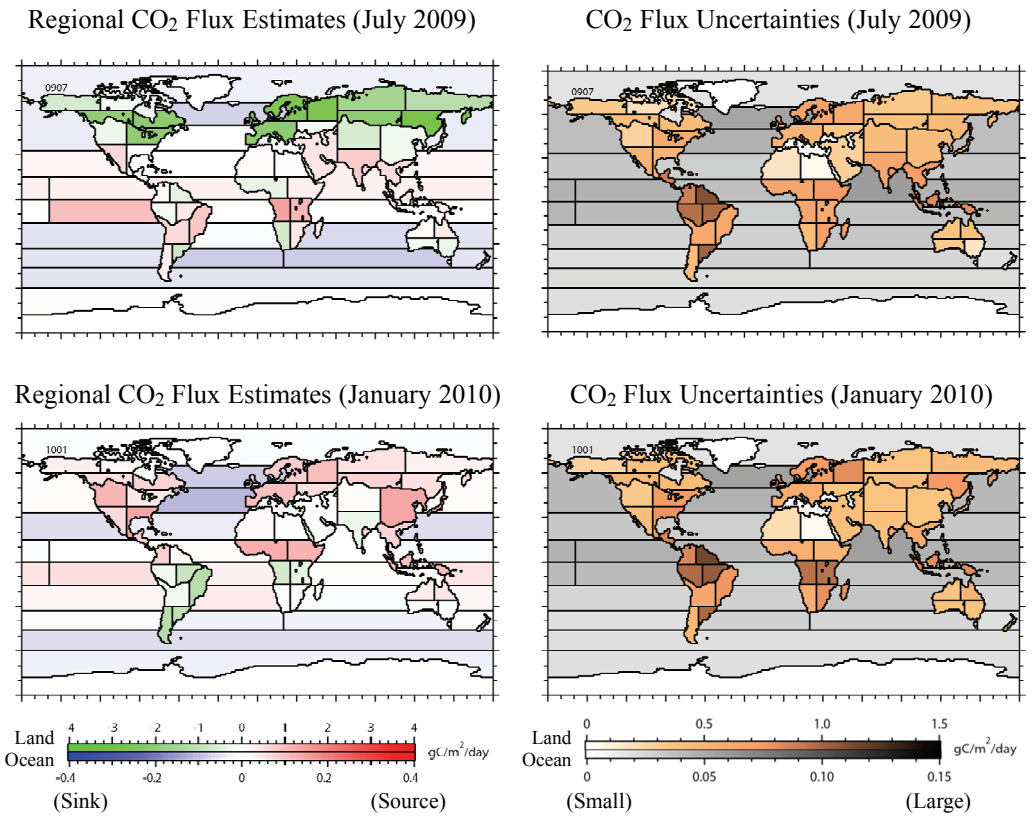


Fig. 5 GOSAT Level 4A data product (version 2.01), showing samples of regional CO_2 flux estimates and their uncertainties. The units used here are g C m^{-2} day^{-1} and represent the net amount of CO_2 (converted to carbon amount in grams) emitted or absorbed per square meter in a day.

Center for Material Cycles and Waste Management Research

Research Laboratory of Material Cycles and Waste Management

Thermal treatment plant

Landfill simulation plant

Since its foundation in 2001, the Center for Material Cycles and Waste Management Research has aimed to realize a society with 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 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

In recent years, greenhouse gas (GHG) emission controls that incorporate the supply chains of products and services, thereby emphasizing the role of consumers rather than producers, have been attracting increasing attention. A country's consumption-based emissions, including those due to global supply chains, reflect the total emissions on which the national economy relies. To design effective emission-control strategies there is therefore an urgent need for each country to elucidate the structural relationship between its domestic economy and the emissions occurring through global supply chains. In this initiative, we consider the structural characteristics of consumption-based emissions in Japan, which in 2005 totaled 1675 Mt CO_2 eq. Given that about 64.3% of Japan's overseas emissions occur in countries and regions other than those included in Annex I of the UNFCCC (United Nations Framework Convention on Climate Change), Japan is actually relying to a considerable degree on emissions that are subject to no international obligations. We are identifying key economic contributors to consumption-based emissions at the commodity level and specifying items of household expenditure that are effective options for both saving money and reducing emissions.

Field study of product and material cycles for managing resources and chemical risk: distribution of heavy metal pollution in the surface soil at an informal electronic-waste recycling site

We performed surficial research on the distribution of heavy metals [lead (Pb), copper (Cu), and zinc (Zn)] in the surface soil at an e-waste recycling workshop near Metro Manila in the Philippines. Our aim was to evaluate the scale of pollution (spot size, small area, or the entire workshop) and to assess heavy metal transport into the surrounding soil environment. On-site length-of-stride-scale (~70 cm) measurements were performed at each surface soil point by using field portable X-ray fluorescence. The surface soil at the e-waste recycling workshop was polluted with Cu, Zn and Pb, which were distributed discretely (Fig. 1). The site was divided into several areas based on the distance from an entrance gate (bottom of the figure) of the e-waste recycling workshop. The three heavy metals had similar concentration gradients in the top-bottom direction. Zn, Pb, and Cu concentrations were estimated to decrease to half of their maximum concentrations at about 3, 7, and 7 m from the most polluted spot, respectively, inside the informal e-waste recycling workshop. Distance from entrances may play an important role in heavy metal transport at the soil surface. Variability analysis of heavy metals revealed vanishing surficial autocorrelation over a range of 0.8 to 2.0 m. Therefore, exposure to heavy metals may influence the health of e-waste workers directly at the original site of exposure rather than indirectly through the surrounding habitat and environmental media.

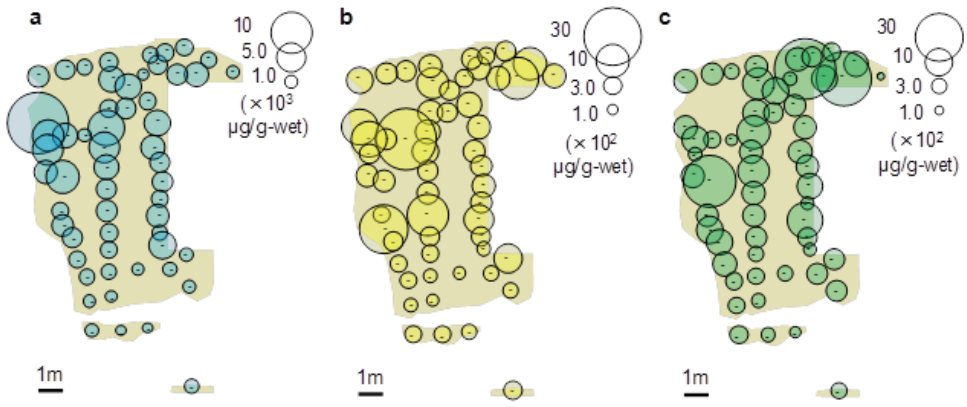


Fig. 1 Surficial distribution patterns of Zn (a), Pb (b), and Cu (c) concentrations in surface soil at an e-waste recycling workshop near Metro Manila.

Proposing management measures toward an international sound material-cycle society

To share knowledge and experiences in environmentally sound management (ESM) of e-waste and to understand the needs of research aimed at promoting ESM in the Asian region, we organized the 9th Workshop on E-waste in cooperation with our counterpart in Thailand—King Mongkut's University of Technology Thonburi—and Chulalongkorn University. At this workshop, the following topics were discussed among researchers, national and local government officials, the private sector, and non-government organizations from Thailand, neighboring countries, Europe, and Japan: (1) the sharing of knowledge of current e-waste recycling in Asia and recent international ESM activities, (2) the discovery of technical and environmental issues in e-waste recycling from the perspective of ESM, (3) process improvement and other possible solutions for

ESM in the Asia region, and (4) related research needs. In referring to the examples of Asia-wide photocopy machine recycling and the limited capacity for recycling of manufacturing waste and electric arc furnace dust associated with e-waste in Asia countries, we discussed the significance of downstream management and appropriate transboundary movement of recyclable materials.

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

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

We developed a methodological model for estimating GHG emissions from waste landfills so as to evaluate simultaneous waste degradation under anaerobic and aerobic conditions. The model included the flow-out carbon dissolved in leachate as an expression of the precipitation intensity in pluvial regions. Modeled dry tomb and Gas-to-Energy landfill systems exhibited higher GHG emission rates than were found with traditional sanitary landfill_system whereas semi-aerobic management gave a 75% reduction in GHG emissions compared with traditional systems. In our field surveys, nitrous_oxide emission was rarely observed in landfills and the impact of nitrous oxide on global warming was less than 5% of that of methane. Nitrous oxide is likely generated through anaerobic heterotrophic denitrification. In contrast, landfills with a higher water level, such as those in pluvial regions or offshore, exhibited higher rates of emission of nitrous oxide.

Test-cell experiments conducted in a Thailand landfill revealed no significant difference in GHG emissions between semi-aerobic and traditionally managed systems. It could be attributable to surface oxygen penetration with poor surface management in the traditional cell, and effective flow-out of organics and low drivers of convective gas exchange because of high ambient temperatures in the tropical_regions, and moisture deficiency through drainage promotion in the semi-aerobic cell. The drainage system in the semi-aerobic cell developed aerobic condition in dry season. We also observed the effect of semi-aerobic management on the biological conversion of nitrogen compounds. Numerical analysis revealed that the oxygen penetration increased with operation time, i.e., with increasing waste degradation, which was caused by temperature difference between the waste layer and the ambient air. It also revealed that the dominant route of oxygen penetration was via the drainage systems. These results suggested that landfill structure and management must be adapted to the conditions of pluvial Asian regions. Control of input and output of water, design of drainage piping, and good surface management are critical in the appropriate operation of semi-aerobic landfills in this region.

Development of on-site wastewater treatment technologies for developing nations

We investigated recent trends and needs in the field of organic waste and wastewater treatment technology for China's rural areas. We developed an

efficient biogas reactor and biogas-purification bioreactor customized to suit the needs of rural Asian regions. The results of continuous 1-year experiments demonstrated that our newly developed biogas reactors could be operated successfully, without acidification or deposit formation, at an organic loading rate of 3 to 18 kg-COD (chemical oxygen demand) m^{-3} day^{-1}. In addition, we constructed a framework for selecting sludge treatment systems for Asian cities on the basis of an algorithm for choosing appropriate liquid waste technologies. There were three types of technical constraint: collection, treatment, and disposal. Techniques such as manual pumping (collection), stabilization ponding (treatment), and composting (disposal) were characterized.

Development of tools for planning waste management systems

We accumulated data on municipal solid waste (MSW) management in several municipalities in Thailand. Most Thai municipalities still rely on municipal solid waste management by landfilling, even though Thailand has achieved greater economic growth than the Philippines, Vietnam, Indonesia, Laos, and Cambodia, where landfilling is the main (and almost the only) solution for MSW management. The Bangkok Metropolitan Administration continues to identify the proximate composition (moisture, volatiles, and ash contents) and heating value of MSW, because it is keen to install incineration processes to reduce the volume of waste to be disposed of. The average moisture, volatiles, and ash contents of MSW in Bangkok Metropolis from 2000 to 2011 were 51.0%, 40.5%, and 8.1% respectively. This suggests that the proximate composition of MSW in Bangkok Metropolis is closer to that in Japan than in other Southeast Asian countries, and that incineration can therefore be used from the perspective of waste quality (Fig. 2).

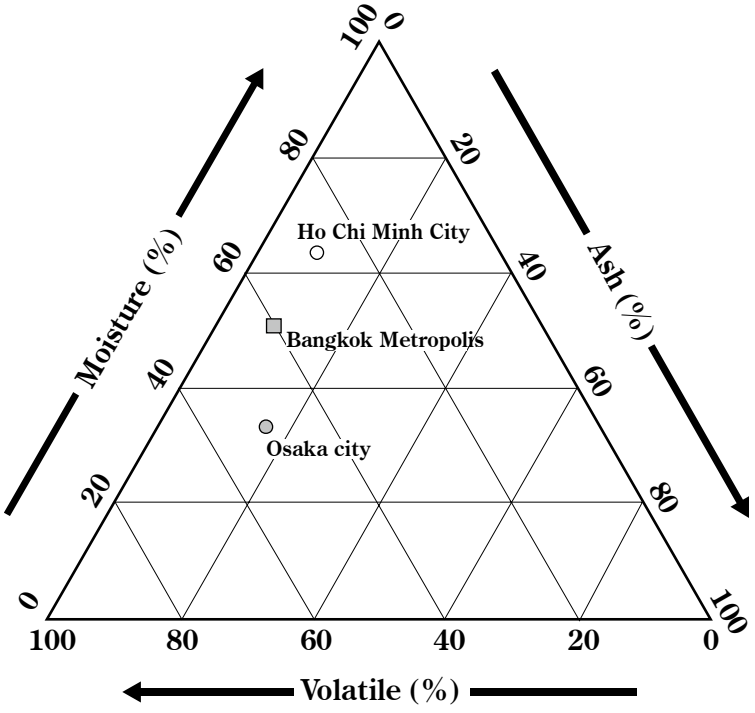


Fig. 2 Proximate compositions of municipal solid wastes in Osaka, Japan, Bangkok Metropolis, Thailand, and Ho Chi Minh City, Vietnam.

(3) Establishment of material-cycle systems by utilizing regional characteristics (Research project 3)

Proper material-cycle systems on various geographical scales need to be established for a sound material-cycle society. This project aims to contribute to regional communities by designing regional systems. It also aims to contribute to the science of material cycles by establishing methodologies for estimating appropriate geological scales for material cycles and formulating concepts for local use of these cycles. In the second year of the project, we reviewed cases of regional material cycles further, following the first year's initial review. We collected the data required to assess sound regional material-cycle systems and analyzed the data in several ways.

Designing a framework for constructing regionally appropriate material-cycle systems

We reviewed cases and studies of regional material cycles and identified several views on regional development. Some regarded the consideration of regional characteristics as necessary for successful regional development, whereas others thought that it simply enhanced the value of regional material cycles. Some expected that alternative regional development would be promoted; however, there was no clear definition of the goals of such alternative development. On the basis of the results of our review, we put forward five visions of regionally appropriate material-cycle systems, namely (1) integration or linking (or both) of industries or technologies to maximize the efficiency of resource use; (2) activation of local communities, with maximization of the use of regional human resources and social capital; (3) use of regional resources at maximum levels of efficiency within sustainable conditions; (4) optimization in time, such as adaptation to population decreases and other social changes; and (5) the use of "clean cycles", i.e., resource circulation that avoids or prevents environmental pollution and damage to human health under integrated management of both resources and toxic substances.

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

We collected the metals and biomass regional-profile data required to design and assess sound regional material-cycle systems. The data included those on the location and capacity of recycling plants and metal refinery plants, the amounts of biowaste and metal-containing waste generated, and the demand for recycled products made from these wastes. The data covered 13 metals (Cu, Pb, Zn, Au, Ag, Pt, In, Co, Li, Nd, Ni, Cr, and Mo) and a variety of biowastes (including organic sludge, livestock excreta, waste oil, waste wood, thinned wood, and unused wood in forests). The regional profile data collected consisted of technology profiles and material flow profiles; these were visualized on maps to represent regional characteristics (Fig. 3).

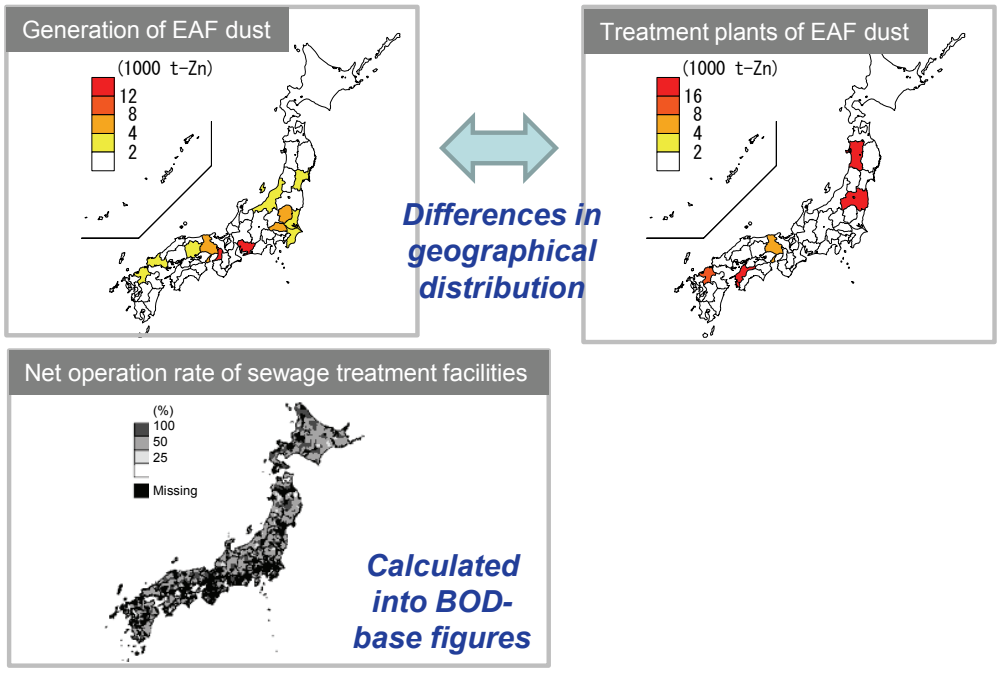


Fig. 3 Visualization of regional characteristics of material flows and related facilities on maps. EAF, electric arc furnace; BOD, biochemical oxygen demand

We then used our data to design regionally appropriate material-cycle systems, and we analyzed how to adapt recycling and waste treatment systems to regions with decreasing populations. The results were based on a life-cycle assessment methodology and showed that reducing the number of incinerators was a promising adaptation. They also showed that the integration of incinerators in small or-medium-sized population areas would benefit the region most in terms of both cost and CO_2 emission reductions, because highly efficient electricity generation systems could be introduced if integration were to occur. We also used a resource generator method to analyze social capital in communities and found that the amount of social capital was correlated with the degree of attachment that residents felt to their local region.

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 MSW incineration plants in western Japan to investigate the current status of energy-from-waste and also the degree of reduction in the amounts of residues. We also investigated the current status of the use of bottom ash as a raw material for cement production. The amount of power generated was 330 to 400 kWh per t of MSW in all of types of incineration plant. Stoker-type plants without ash melting furnaces could be operated with reduced supplies of heat from outside. The ashes could be transported from incineration plants to cement manufacturers for recycling them, even over a long distance.

We continued our biomass gasification study to further develop efficient processes of gas recovery followed by gas conversion. To investigate the conversion of producer gas ($CO+CO_2$), NiO/SBA-15 (nickel (II) oxide with a mesoporous silica) was prepared by post-synthesis and direct synthesis methods. The concentration range of NiO loading required to obtain monodispersed NiO particles was affected by the combination of metallic salt precursors and acids. NiO/SBA-15 prepared by post-synthesis favored methanation, whereas that obtained by the direct synthesis method favored the reverse water-gas shift (RWGS) reaction. For methanation, $CO+CO_2$ conversion increased with increasing NiO loading. Although the NiO loading did not affect CO_2 conversion to CO by the RWGS reaction, it influenced the CO selectivity.

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

We used technical feasibility studies with numerical simulations to summarize the technical requirements for disposing of wastes contaminated with radiocesium. As part of landfill modeling, we modeled a concentration boundary that was combined with the results of batch-type and column-type leaching tests. In addition, a conceptual model to calculate the effect of semi-aerobic landfill operation was constructed by using the multiphysics numerical simulation code COMSOL. Experiments revealed that the size of the lysimeter column used to simulate landfill stabilization affected the leachate concentrations of ions, organics, and pollutants. We are now evaluating the mechanism behind these column size effects. We created a material flows database of inorganic industrial wastes in a certain prefecture, and we simultaneously built a GIS (geographic information system) that included such features as generation sources, treatment facilities, final disposal sites, and quantity of waste movements.

(3) Establishment of appropriate measures for regional environmental restoration and domestic liquid-waste treatment

We investigated GHG emissions from a *johkasou* (Japanese household wastewater system) and a vault toilet. We developed methodologies for developing CH_4 and N_2O emission factors for these wastewater treatment systems. The results of our field survey contributed to the National Greenhouse Gas Inventory. We also examined the effects of water-saving devices on water and electricity consumption in houses. We developed a robust *johkasou* system as part of this research program, thus determining the configuration required to resist earthquakes.

We also conducted a pilot-scale purification experiment for eutrophic lake waters, using submerged plants and floating hydroponic aquatic plant systems. The results showed that removal of nitrogen and phosphorus improved, and the growth of filamentous algae and microalgae was suppressed, when floating

aquatic systems were combined with a submerged plant system. In addition, we used iron-casting-process wastes as environmental restoration materials. We found that the wastes had good ion-exchange capacity, adsorption, and pH buffering. We also examined hydrothermal treatment as a pretreatment in the synthesis of acetone from waste biomass. Excess sludge and rice husks were suitable for acetone synthesis because of their high acetate-formation potential, whereas seaweed was not suitable owing to the leaching of potassium, which inhibits the catalysis of acetone.

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

To study the proper management of asbestos, we applied a rapid-screening method that uses polarized light microscopy to the examination of asbestos-containing materials in wastes from the tornado that occurred in Tsukuba in 2012. Examination of 12 items was completed within about 2 h—faster than with the conventional JIS(Japanese Industrial Standard) method. The accuracy with which asbestos was identified with this method was the same as that of the conventional method. To study proper treatment technologies for persistent organic pollutants (POPs), we conducted experimental combustion of hexabromocyclododecane (HBCD), a POP newly restricted under the Stockholm Convention. We confirmed that the HBCD destruction efficiency was over 99.9999% and the levels of formation of brominated dioxins and furans were small. To study technologies for recycling hard-to-recycle materials, we investigated using the chlorine-volatilization process to remove lead from cathode-ray-tube glass. We found optimum chlorine additive conditions under which the volatility of lead was more than 99%. To examine technologies for restoring inappropriate landfill sites, we studied methods of preventing fires at temporary depots, the safe compression and packing of waste generated by decontamination, and ways of collapsing the slopes at landfill sites.

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

To enable products made from converter steelmaking slag to be used for marine applications, we investigated the leaching of alkali substances from these products and the subsequent rise in pH of seawater. Experiments were performed in a large-scale tank (L 6.5 m × W 0.5 m × H 1.2 m) with an artificial seawater flume. We used five kinds of sample, namely three kinds of steelmaking slag with particle sizes of 0 to 30 mm, 15 to 30 mm, or 30 to 85 mm; artificial stone (i.e. solidified steelmaking slag subjected to a hydration reaction); and reformed soil (i.e. dredged soil mixed with converter steelmaking slag). The pH values of seawater sampled from 40 parts of the tank were simultaneously determined, and maps of pH distribution with time were drawn. The pH of seawater in the case of

the steelmaking slag rose by 0.16 to 0.35, and slags with different particle diameters showed different behaviors. The rise in pH of the seawater with the artificial stone or reformed soil was within 0.04.

3. Promotion of seed and fundamental research

(1) Systems approach and policy study of life-cycle resource management

We developed a methodology to adjust material flows that showed material balance inconsistency because of limitations in the availability of resource trade data. The methodology was applied to the analysis of international material flows.

Schemes for recycling waste batteries in Denmark and Switzerland were investigated. We found that collection cost was incorporated into the price of batteries; the municipality's role in collection was much larger than that in Japan, and municipalities were compensated by producers for the collection costs incurred, resulting in stronger motivation for municipal collection. Domestically, our survey of regional basic plans for a sound material-cycle society showed that the plans were not used effectively, especially in terms of their function as visions for a sound material-cycle society.
We also began studying the waste issues confronted by the elderly and the issues associated with the informal recycling sector in developing countries.

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

We are continuing to develop chemical analysis methods for identifying hazardous chemicals or related compounds in various wastes and circulative resources from their decompostion and resource elements. We applied *in vitro* bioassays to new materials such as flame retardants and biofuels, and we further developed an overall toxicity evaluation system. We newly established a rapid vapor-pressure measurement method for novel or emerging brominated flame retardants. The UNIFAC model used for predicting physicochemical properties was evaluated in terms of thermodynamic consistency. A multi-fuel production system was developed to produce fuel oil and biogas from waste greases. We successfully achieved a scale-up of the biofuel production reactor to 100 L. As part of the development of new technologies for lifetime improvement of rechargeable batteries, we found that high pressure increases the charging efficiency of lead acid batteries.

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

We published a web database on options for sustainable materials management. It comprises more than 800 articles from Japanese Acts that deal with the handling

and management of materials, resources, and waste, and it categorizes them into six basic treatment options: (1) exposure prevention, (2) closure of flows, (3) gate-checking, (4) information management (notification and traceability), (5) resource supply and use, and (6) establishment of management systems. For a database on international material flows, we collected data on the movements of the scarce metals needed for new energy technologies such as wind turbines and fuel cells, and we examined the consistency of these time-series data. We also collected data on the metal resource contents of electronic products, including new products such as smartphones. Data on the proximate composition of MSW in Southeast Asia were displayed in a triangle diagram to show the applicability of waste treatment technologies.

4. Promotion of a collaborative R&D project

(1) R&D promotion and partnership activities in the Asian region

In 2012, we launched the Collaborative Research Laboratory in Bangkok, Thailand, in a partnership with two Thai universities that lead the field in waste management. This laboratory allows us to conduct more field-based research and to build the research capacity of researchers from Japan and Thailand. We aim to expand the reach of Japanese waste management technology and methodology to the Asian region to provide better and more appropriate waste management. To accomplish this goal, a better understanding of waste management in the region through first-hand data and knowledge and an increase in the number of our field studies, joint studies, and researcher exchanges within the region are essential.

We are also starting to disseminate information on disaster waste management. We have conducted two forums in Bangkok to communicate information on flood waste management, and we have also drafted flood waste management guidelines for Bangkok. The region is very vulnerable to natural disasters such as floods and earthquakes, and to mitigate the risks to the environment and human health we plan to further help countries in this region—especially developing countries—to collect case studies.

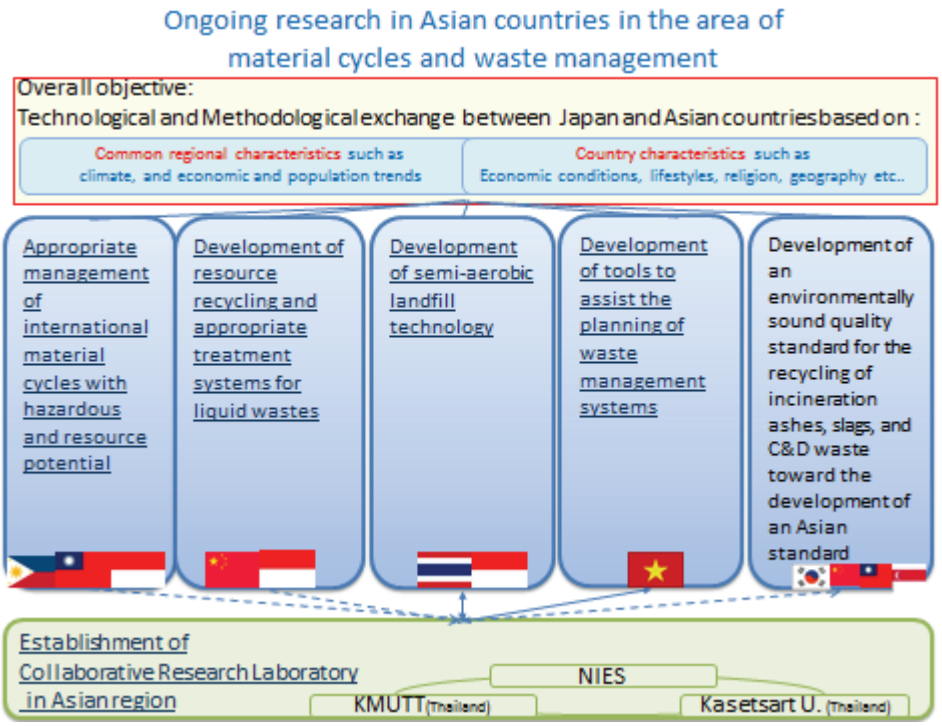
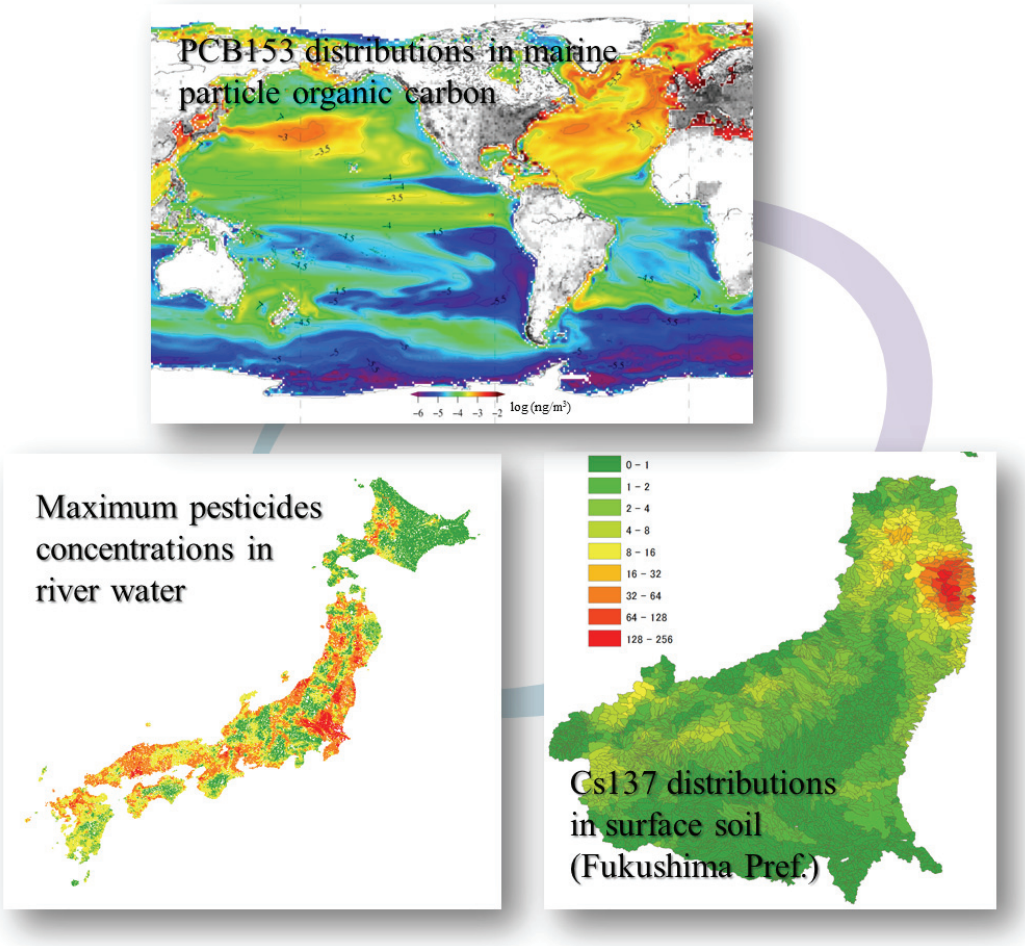


Fig. 4 Major themes of the research we conducted in the Asian region in FY 2012.

Center for Environmental Risk Research



Stratified modeling of global and regional distributions of pesticides, radioactive substances, and persistent organic pollutants at various spatial scales by using PeCHREM/G-CIEMS (Pesticide Chemicals High-Resolution Estimation Method/Grid-Catchment Integrated Modeling System) and FATE (Finely Advanced Transboundary Environmental model).

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 are concentrating 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 2012, the Center for Environmental Risk Research started a key research program on innovation in the evaluation and management of chemical substances. The program consists of three fundamental research projects that are run concurrently and are designed to implement environmental action plans that take policy needs into account. In addition, we have continued to develop infrastructure for environmental research by establishing a reference laboratory and chemical substance databases.

Research Program on Risk Assessment and Control of Environmental Chemicals

In recent years, programs for managing chemical substances have incorporated assessments of their impact on living organisms in the environment. However, the concept of ecosystem protection is not fully entrenched in risk assessment. Accordingly, we need to focus on the development of techniques for evaluating ecological risk. Conventional techniques for hazard assessment may not be able to fully evaluate the effects of nanomaterials on human health and ecosystems. Strategic approaches to managing a variety of chemicals need to be established to enable more effective control of the risks they pose. To address these issues, we have been conducting a research program on innovation in the evaluation and management of chemical substances. This program consists of three projects described below as projects 1 to 3, on studies of research of risk to ecosystems, nanomaterials toxicology, and management strategies for the risks posed by numerous chemical substances, respectively.

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 functions. For this purpose, we made a

tri-trophic (three-species) biotic community model that used the algae–zooplankton–fish system. We call this model the "tri-trophic ecological risk assessment model" (TERAM). The model includes the temporal dynamics of chemical exposure to each species, interspecific interaction between adjacent trophic levels (prey–predator interaction), the kinetics of toxicants (i.e. bioaccumulation) in the fish's body, the dose–response function for various endpoints (Fig. 1), and the age structure of fish stocks. These comprehensive properties of the model have permitted us to integrate various ecotoxicity data (i.e. acute mortality, reproductive and growth inhibition of fish, acute immobility and reproductive inhibition of *Daphnia*, and growth inhibition of algae) estimated independently for the three species with chemical information on bioaccumulation and with ecological information on the target species' life history or phenological schedule of growth and reproduction in the field (Fig. 1). Ecological risks are evaluated uniformly by reducing the population growth rate of the top species. For most chemicals, however, complete sets of ecotoxicity data are hardly relevant. Therefore, to supplement lacking ecotoxicity information, we have developed an acute-chronic extrapolation method based on an ecotoxicity database prepared by the Ministry of the Environment. As case studies, we have run population dynamics simulations for several agrochemicals on the basis of ecotoxicity data and environmental concentrations measured in the Kokai River (Ibaraki, Japan).

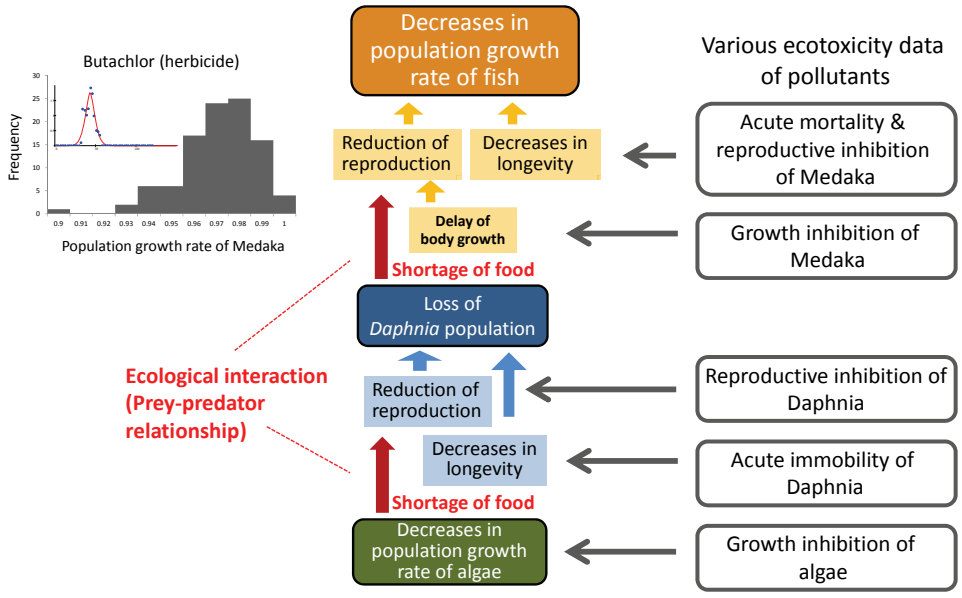


Fig. 1 Schematic drawing of the tri-trophic ecological risk assessment model. The model consists of three dynamic components, each of which represents one of the three trophic levels, i.e. algae, zooplankton, and fish. The prey–predator interaction between adjacent trophic levels follows the standard ecological modeling method. For the fish population there are three sub-models. They simulate the chemical's dynamics in the fish's 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. Various kinds of ecotoxicity independently affect different endpoints at the three trophic levels. Simulation results for the herbicide butachlor are shown in the graph at top left.

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. We proposed an extended reproduction test using *Daphnia magna* for quantifying the effects 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 have developed a receptor model that simulates sex changes in *D. magna* under specific exposure

scenarios, as well as a biology-based reproductive inhibition model (the DEBtox model) that predicts fecundity loss due to the acute and chronic effects of chemicals. Posterior distributions of model parameters were estimated by using Bayesian Markov chain Monte Carlo simulations. Finally, we used stochastic population dynamics simulations based on the estimated posterior distributions of model parameters to evaluate the population-level effects of endocrine disruption in terms of reduction in population growth rate.

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

Our second, and current, nanotoxicology project started in FY 2011. 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 embryos and sac fry of fish in the ecotoxicological evaluation of titanium dioxide (TiO_2) nanoparticles. In addition, as part of this second project, we intend to develop an *in vitro* system of nanoparticle exposure at the air–liquid interface for toxicity screening of nanomaterials.

In the carbon nanotube study, mice were injected intrathoracically or exposed to multi-walled carbon nanotube aerosols for 2 h/day for 5 days inside inhalation facilities developed during the first project. The mice's lung tissues and thoracic cavities were examined histopathologically and biochemically. Serious lesions with hypertrophy of connective tissues were observed. They were accompanied by increases in the levels of inflammatory biomarkers in the bronchoalveolar or thoracic lavage fluids.

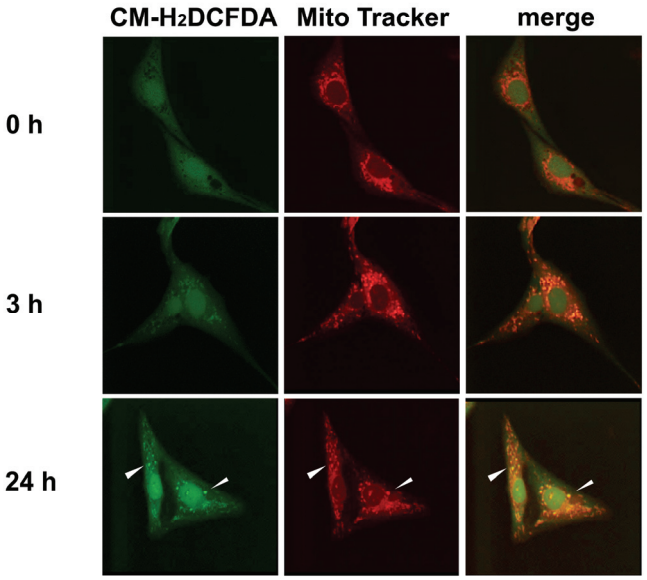


Fig. 2 Localization of reactive oxygen species (ROS) in BEAS-2B cells after exposure to $AgNO_3$. Cells were incubated with 1.0 μM $AgNO_3$ for 0, 3, or 24 h and then exposed to 2 μM CM-H_2DCFDA and 500 nM MitoTracker® for 30 min. Localization of ROS was determined by superimposing green fluorescence (DCFDA-derived CM-H_2DCFDA) and red fluorescence (MitoTracker®). CM-H_2DCFDA is a chloromethyl derivative of H_2DCFDA. (T. Miyayama et al. 2013. Toxicology 305: 20–29)

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 (Fig. 2). 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. The generation of oxidative stress in mitochondria was measured by using MitoTracker® (red fluorescence) in cells loaded with DCFDA (dichlorodihydrofluorescein diacetate; green fluorescence). Co-localization of the two fluorescences in the cells indicated that silver selectively caused oxidative stress in the mitochondria. In *in vivo* experiments, we studied the inflammatory potency and neurobehavioral changes caused by silver nanoparticles. 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 and cellular uptake *in vitro* study were performed with these fluorescence-tagged dendrimers. For effective exposure of mammalian cells to nanoparticles *in vitro*, we used the Cultex® system, with some modifications. We measured the deposition rates of nanoparticles at the air–liquid interface of cultured cells.

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 with or without ultraviolet irradiation 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. We next intend to evaluate the cytotoxicity of TiO_2 nanoparticles dosed with trace amounts of heavy metals to investigate whether concomitant metals in TiO_2 significantly modulate the toxic effects of nanoparticles.

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

developing a model for predicting spatiotemporal changes in agricultural chemicals. Assessment methods that consider temporal variations in emissions and risks to the aquatic environment are studied as major examples of the theme; PeCHREM/G-CIEMS (Pesticide Chemicals High-Resolution Estimation Method/Grid-Catchment Integrated Modeling System) models are used. Sub-theme 1-2 focuses on developing and studying emissions and exposure scenarios over the entire life cycles of substances, from manufacture to disposal. Flame retardants and PFOS (perfluorooctane sulfonate) have been selected as the current targets of the study. Sub-theme 1-3 focuses on developing a global multimedia model (the Finely Advanced Transboundary Environmental model; FATE) for predicting the fate of POPs. We are exploring the development of an assessment methodology based on the global distributions of these substances. Theme 2 focuses on strategies for managing the different dimensions of risk posed by various chemical substances in society. We are considering a variety of characteristics of risks from chemicals in various social contexts in terms of chemical spatiotemporal variation and life cycle, the uncertainties of scientific knowledge, and the variable nature of impacts and social receptivity. We intend to 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 2012, we advanced the validation of the PeCHREM/G-CIEMS models for fungicides and insecticides as part of sub-theme 1-1. We observed agreement between model and observation in 55% of all chemical–river pairs in a field survey of fungicides and insecticides. We obtained new emission information of brominated flame retardants by using model-room experiments as part of sub-theme 1-2. We found different phase distributions of polybrominated diphenyl ethers (PBDEs) among the dust, floor-adsorbed, and gas phases for different homologs of PBDEs. In sub-theme 2 we found that there were differences in understanding of the basic concept of risk in science and society.

This year we specifically report our achievements under sub-theme 1-3, in which we improved the FATE model for a variety of POP-like chemicals. We developed a new module that parameterizes physicochemical properties, such as partitioning and sorption coefficients, and degradation half-lives, by using QSPR (quantitative structure-property relationship) models. Using this FATE-QSPR combined scheme enabled us to perform systematic simulations for a large number of chlorinated and brominated organic compounds. We used the improved FATE to investigate the long-range transport potential (LRTP) and overall persistence (P_{ov}) of chlorinated and brominated organic compounds. To this end, we performed source-receptor analyses and estimated the global average of the imported fraction in the atmospheric boundary layer as a new LRTP metric.

Figure 3 shows the results for source attribution and the relationships between P_{ov} and LRTP.

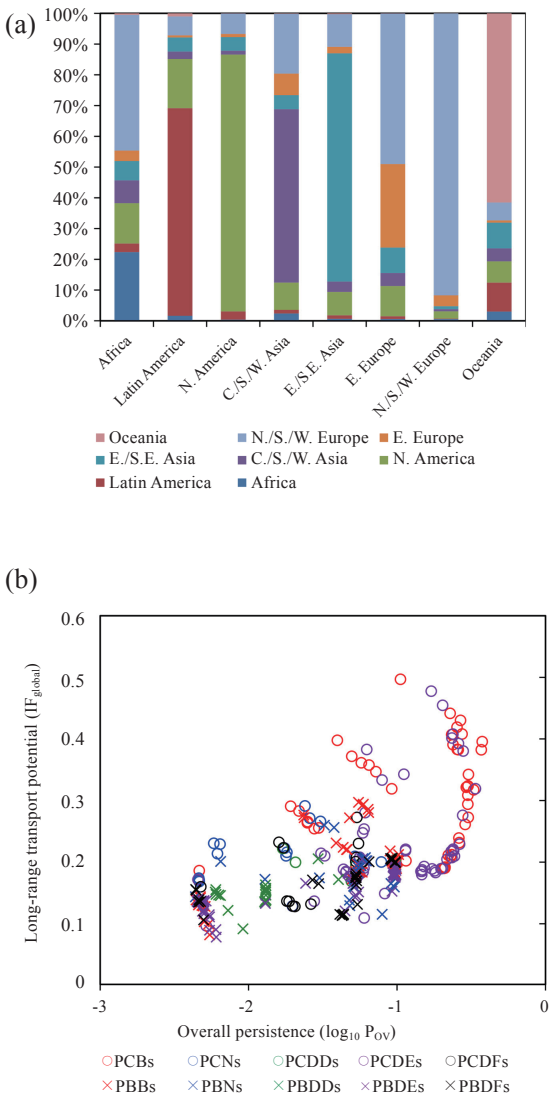


Fig. 3
(a) Predicted relative contributions (%) from source regions to polychlorinated biphenyl (PCB) contents in the atmospheric boundary layer (ABL) in receptor regions.
(b) Relationships between predicted overall persistence (P_{ov}) and long-range transport potential (LRTP) of chlorinated and brominated organic compounds. Global average of imported fractions in the ABL in receptor regions, weighted by the contents (IF_{global}), is used as the LRTP metric.

Development of infrastructure for environmental research

To establish infrastructure for assessing and managing the risks posed by chemical substances, we performed the major task of gathering environmental-risk-related information obtained from research. We need to constantly update testing methods for the ecological assessment of chemical substances in response to the manufacture and importation of chemical products with novel characteristics, such as nanomaterials, and the discharge of pharmaceuticals into the environment. From this perspective, we intend to improve our environmental-risk-related activities. This involves the development of a chemical substance database, the provision of information from the database, and our role as a reference laboratory for eco-toxicity testing. Throughout these projects, we will continuously update the information in our database relating to risks from chemical substances and will make the information easier to access and use. We will also promote environmental risk assessment by increasing the reliability of ecological impact assessment data.

(1) Establishment of a reference laboratory for ecological hazard assessment

We performed the following projects aimed at furthering our role as a core laboratory that develops standardized eco-toxicity tests in Japan and abroad, promotes techniques for eco-toxicity testing, improves the reliability and accuracy of toxicity data for environmental risk assessment, and supports the development of infrastructure such as testing laboratories in Japan.

i. **Collaboration and cooperation with institutions inside and outside Japan.** By using the latest research trends and social situations relating to environmental risks, we are collaborating with the relevant institutions from Japan and abroad to develop new test methods. This year, we organized a validation test of whole effluent toxicity testing by using industrial effluent samples in cooperation with testing laboratories and factories; our ultimate aim is to introduce eco-toxicity testing in effluent management systems. Members of our research team also attended a conference of international experts aimed at developing OECD (Organisation for Economic Co-operation and Development) test guidelines.

ii. **Promotion and improvement of eco-toxicity tests.** We are working on promoting primary knowledge and techniques for eco-toxicity tests and improving the reliability and accuracy of test data. As part of these activities, since 2011 we have held practical training seminars for environmental research institutes in local government, companies, and universities that aim to introduce eco-toxicity tests. By teaching primary knowledge and techniques for eco-toxicity testing through lectures, practical training, and tours of our laboratory, we are supporting the start-up of eco-toxicity testing laboratories. This year we held seminars twice (in May and December): one for teaching tests on daphnids (water fleas) and another for teaching tests on zebrafish. Each time, more than 30 participants from various organizations (companies, research institutes, and universities) enjoyed the seminars and benefited from forging new relationships between participants (Fig. 4).

iii. **Development of, and support for, infrastructure for eco-toxicity tests.** We have developed an efficient system for maintaining and supplying the organisms (e.g. medaka and water fleas) used in tests in Japan and abroad. We provide these organisms to testing laboratories.

Fig. 4
Practical training for acute toxicity testing using *Daphnia magna* (water flea).

(2) Development of chemical substance databases and dissemination of data

As part of this project we have been continuously updating and improving our chemical substance database and a website named Webkis-plus, which is open to the public, as well as another, related database and a website named EnvMethod, which covers methods for analyzing various chemical substances in the environment. We have also been developing new databases and websites featuring the results of our research efforts (Fig. 5). This fiscal year our database work was focused on the following:

i. We updated and improved the Webkis-plus database. The latest information was added, including shipment volumes of agricultural chemicals, environmental concentrations from a survey by the Ministry of the Environment titled "The State of Chemical Substances in the Environment," amounts of chemical substances manufactured and imported, PRTR (Pollutant Release and Transfer Register) emission and transportation amounts, and the results of risk evaluations.

ii. We updated and improved the EnvMethod database. Details of the analytical methods used in the environmental surveys in "The State of Chemical Substances in the Environment" were added to the database.

iii. We began developing a new database of survey results and a related website based on GIS mapping.

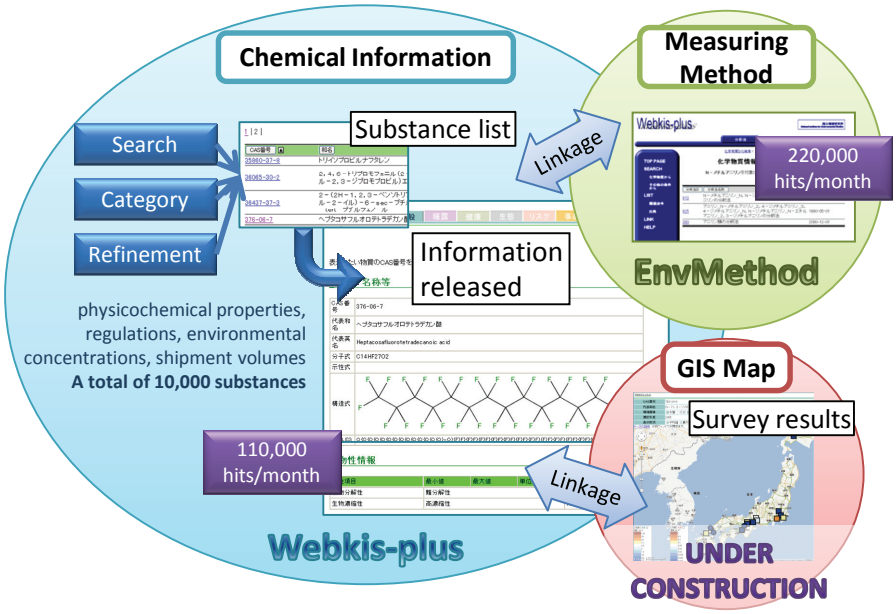


Fig. 5 Schematic design of websites that have been, or are being, developed. The three websites and related databases are effectively linked by chemical substance code and medium. Everyone can access Webkis-plus and can easily obtain chemical information via input of a search word or categorized list. The Webkis-plus database contains information on 10,000 substances, including their physicochemical properties, regulations, environmental concentrations, and shipment volumes.

Center for Regional Environmental Research

Field monitoring in Gamo Lagoon, facing Sendai Bay (Japan), in June 2011. The 2011 tsunami caused drastic changes in the environment and biota in the lagoon.

The bivalve *Laternula marilina* (a) and the gastropod *Cerithidea rhizophorarum* (b) were nearly extirpated by the tsunami. Dead bivalve shells (*Macoma* spp.) were found in the dead rhizomes of reeds (c). New recruitment of *Assiminea hiradoensis* occurred in fall 2011 (d).

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 2012, 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); three cross-discipline research projects (Coordinated Study of Environmental Emissions and Behavior and Effect of Metals in High-tech Products, Focusing on their Lifecycles, Flux Estimation from Sediment in Nutrients and Global Warming Gas by MRI and Stable Isotope Analysis, and A Study of PM in Urban Atmosphere for Reduction of PM and Evaluation of Toxicity and Health Impact of PM Based on Chemical Compositions); and two special research projects (Deterioration of Sedimentary Environments and Assessment of its Impacts on Benthic Fauna in Coastal Seas close to Urbanized Areas, 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 project concerning multimedia modeling and long-term monitoring of radioactive substances emitted from the Fukushima Daiichi Nuclear Power Plant. Most of the projects are collaborations with other centers at NIES. Additionally, there are two long-term monitoring programs: the Regional Atmospheric Monitoring Program and the GEMS (Global Environment Monitoring System)/Water Program, which is a collaboration with the Center for Environmental Biology and Ecosystem Studies.

Below, we give brief accounts of some of the important results of the Center's research in FY 2012.

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 all 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 observations and modeling

In Project 1, Analysis and Evaluation of Multi-scale Air Pollution by Integration of Observations and Modeling, we are examining air quality issues ranging from 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 analyzed speciation and variability of non-methane volatile organic compounds (NMVOCs) measured during an intensive field campaign conducted jointly near Shanghai, China, with the Institute of Atmospheric Physics at the Chinese Academy of Sciences and the Japan Agency for Marine-Earth Science and Technology. Two methods were used to quantify NMVOCs. One was gas chromatography–flame ionization detection/mass spectrometry and the other was proton transfer reaction–mass spectrometry. Combining these two techniques enabled us to obtain ambient data on a total of 18 NMVOCs. Temporal variations in NMVOC levels were examined in conjunction with variations in the levels of tracers of air pollution emitted from combustion sources. During the latter part of the field campaign, elevated concentrations of several NMVOCs as well as carbon monoxide (CO) and acetonitrile (CH_3CN) were observed when intensive burning of crop residues took place near the sampling site. The temporal variations in CH_3CN and CO levels showed very similar behaviors, including day-to-day variations and sharp peaks within a day. They occasionally showed huge peaks, with maximum mixing ratios exceeding more than 1.0 ppbv for CH_3CN and 900 ppbv for CO. With the peaks of CH_3CN and CO we observed the enhancement of signals from furan. The observed NMVOC concentrations were compared with the results from a regional chemistry-transport model for Asia. The modeled concentrations underestimated the observed concentrations by a factor of 3 to 5 for several NMVOCs, implying that current emissions inventories are missing a number of sources for these

NMVOCs.

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, a high sulfate mass concentration (about 35 μg m^{-3}) was observed on 25 July 2012. Simulation results from SPRINTARS (by T. Takemura at Kyushu University) showed that the high-sulfate region extended from north-east China to northern Kyushu. This indicates that the high-sulfate event observed at Fukuoka was caused by trans-boundary air pollution, even in summer. Aerosol chemical species were also measured with an aerosol chemical speciation monitor at Fukue Island, Nagasaki. High-sulfate events were observed at Fukue in January and February, 2013. Back trajectory analysis revealed that these events represented trans-boundary air pollution.

The Modeling Team has decided on the framework for a modeling system to simulate the air quality in East Asia and, in particular, to estimate in more spatial detail the air pollution structure in Japan. The modeling system consists of the regional weather simulation model WRF (Weather Research & Forecasting Model, ver. 3.3.1) and the regional chemical transport model CMAQ (Community Multi-scale Air Quality Model, ver. 4.7.1) with two nests (three domains) within East Asia (Fig. 1). Domain 1 is a 60-km-resolution domain that includes the whole of East Asia, as well as India and the majority of Southeast Asia. This domain setting enables the model to compare model calculations with the shipborne measurements by *the Ozone Monitoring Team* in Southeast Asia. Domain 2 is a 15-km-resolution domain covering the whole of Japan, including Cape Hedo on the northern tip of Okinawa Island, the location of the NIES CHAAMS (Cape Hedo Aerosol and Atmosphere Monitoring Station). Domain 3 has smaller-area coverage with 5-km resolution that is focused mainly on air quality issues in metropolitan areas of Japan, such as Kanto, Kinki, or Kitakyushu. Some trial simulations to tune the system with tentative emission data were performed this year.

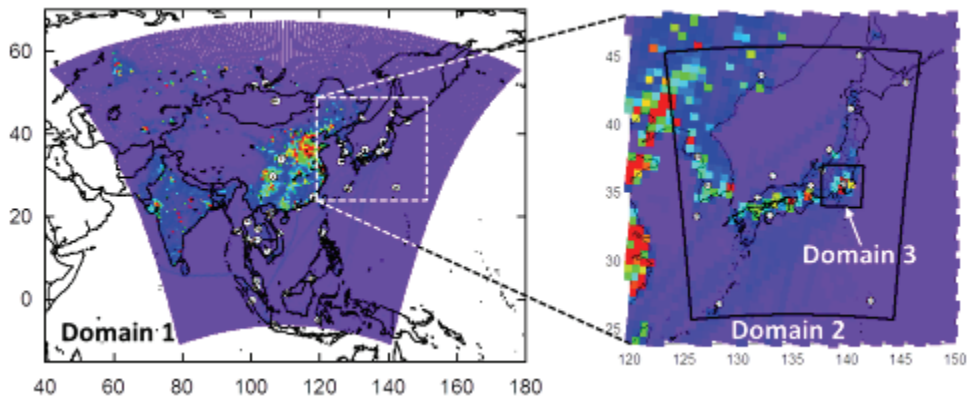


Fig. 1 The three nested domains of the East Asia air quality modeling system. Colors denote the annual emission intensity of SO_2.

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 in the ECS and their impact on marine ecosystems. We made the following progress in our research in FY 2012.

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 sub-catchment of the Changjiang), and we applied the system to the entire Changjiang basin. A simulation (2000–2010) of the total river discharge (FLOW) and water quality indicators showed that the annual mean total river discharge at the mouth of the Yangtze River was 939.1 km^3 and the average yearly amounts of pollutants transported were 180.9×10^4 t of nitrate nitrogen (NO_3-N), 5.3×10^4 t of nitrite nitrogen (NO_2-N), 16.7×10^4 t of ammonium nitrogen (NH_4-N), and 13.8×10^4 t of total phosphorus (T-P). According to the existing research, the amount of NO_3-N passing the Yangtze Datong Observation Station was 78.2×10^4 t in 1985, 106.7×10^4 t in 1990, and 130.3×10^4 t in 2000. This simulation implies that the average yearly NO_3-N amount of 180.9×10^4 t in the last decade has increased by about 50×10^4t compared with the previous decade's. In addition, according to observations at the Datong Observation Station from 1980–1990, the mean yearly amount of NO_3-N was 63.93×10^4 t; of NH_4-N, 11.98×10^4 t; of NO_2-N, 0.79×10^4 t; and of total phosphorus (T-P), 8.36×10^4 t. Comparison with our simulation results indicated that NO_3-N flows in the 2000s were about three times those in the 1980s; NO_2-N flows were more than five times, and NH_4-N flows increased by about 30%. To validate the model simulation, since 2011, with the cooperation of the Institute of Geographic Sciences and Natural Resources Research at the Chinese Academy of Sciences, we have been observing water quality indicators at the Datong Station. Figure 2 shows the observation results for both total river discharge and water quality indicators (NH_4-N, NO_3-N, and T-P) in 2011–2012. From these observations, we estimated that the annual total FLOW was about 642 km^3 in 2011 and 962 km^3 in 2012. Accordingly, the amount of NH_4-N transported to the ECS was about 27.1×10^4 t in 2011 and 45.6×10^4 t in 2012—larger than our estimate. However, the respective amounts of NO_3-N were about 108.5×10^4 t and 152.2×10^4 t, and those of T-P were about 10.5×10^4 t and 12.0×10^4 t. These values were in the same range as our simulation results.

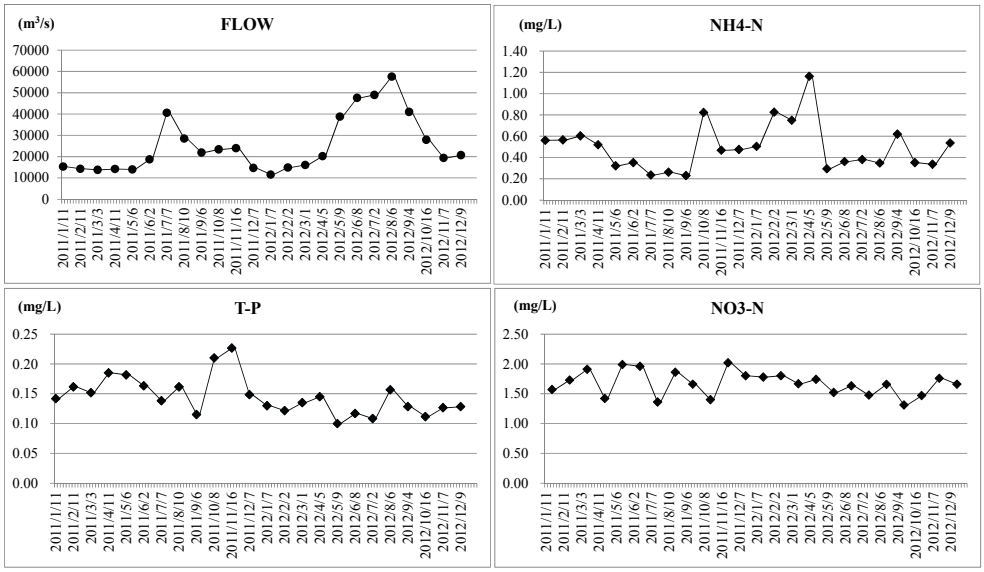


Fig. 2 Total river discharge (FLOW) and water quality indicators [ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), and total phosphorus (T-P)] observed at the Yangtze Datong Station in 2011–2012.

To assess water quality and the planktonic ecosystem, we measured the spatial distributions of turbulent mixing intensity and nitrate over the continental shelf in the ECS in July 2012. This cruise observation revealed that strong turbulent mixing caused by tidal flows often extended from the ocean bottom to just below the pycnocline (Fig. 3). These findings suggested that tidal mixing has a large impact on nutrient supply from the bottom to the upper layer across the pycnocline. A large-scale incubation test of the dinoflagellate *Prorocentrum dentatum* showed that its vertical migration pattern is controlled partly by changes in the specific gravity of seawater, implying that the depth of accumulation of this species depends on the difference in specific gravity between the algal cells and seawater. We incorporated the knowledge we obtained from the laboratory experiments into our biogeochemical model of the ECS. The improved model reproduced the formation of the subsurface chlorophyll-*a* maximum on the continental shelf in the ECS; we had frequently observed this maximum on previous research cruises. The simulation results implied that *P. dentatum* observed in the early summer was transported horizontally from the Changjiang estuary to the central ECS while gradually sinking from the surface to the subsurface layer.

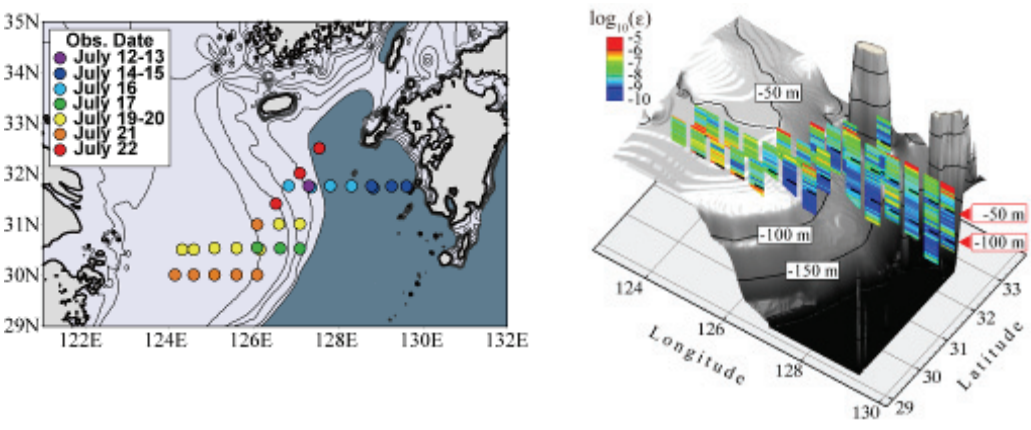


Fig. 3 (Left) Geographic locations of field measurements in the East China Sea (ECS) superimposed on bathymetry. Contour interval is 20 m. (Right) Three-dimensional distribution of turbulent mixing intensity measured over and around the continental shelf in the ECS. Warm (cold) colors indicate strong (weak) mixing intensities.

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 monitoring 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 investigated the contribution of herbaceous vegetation to the control of nitrogen leaching from the root zone in a conifer plantation that was being thinned at different intensities—unthinned, weakly thinned, and intensively thinned. By harvesting and chemically analyzing herbaceous plants in late summer, we confirmed that an increase in thinning intensity clearly worked the growth of herbaceous plants and their nitrogen assimilation. Also, a vertical one-dimensional unsaturated infiltration analysis using the concentration of nitrate nitrogen observed in the soil water revealed that the total amount of nitrogen leaching from the root zone in the intensively thinned plantation was only about 3% of that in the unthinned area during the snow-free season. These results suggest that the well-developed herbaceous vegetation resulting from intensive thinning plays an important role in controlling nitrogen leaching from conifer plantations.

We quantified *in situ* primary and secondary production in Lake Kasumigaura every month in 2012 by using nonradioactive methods such as fast repetition rate fluorometry (for primary production) and assays of bacterial productivity with bromodeoxyuridine (for secondary production). We found that primary production was low when the concentration of chlorophyll-a or the biomass of *Microcystis aeruginosa* (measured as 16S rRNA copies/mL on the basis of RT-PCR) was high, causing algal bloom (Fig. 4). Bacterial secondary production at the center of the lake was lower than at the other sampling points (Takahamairi Bay or Tsuchiurairi Bay). Secondary production ranged from 2.4 to 4.2 μg m^{-2} s^{-1}, with an average of 3.4 μg m^{-2} s^{-1}, corresponding to approximately 40% to 60% of the primary production. This ratio is a little more than that reported in oceanographic studies.

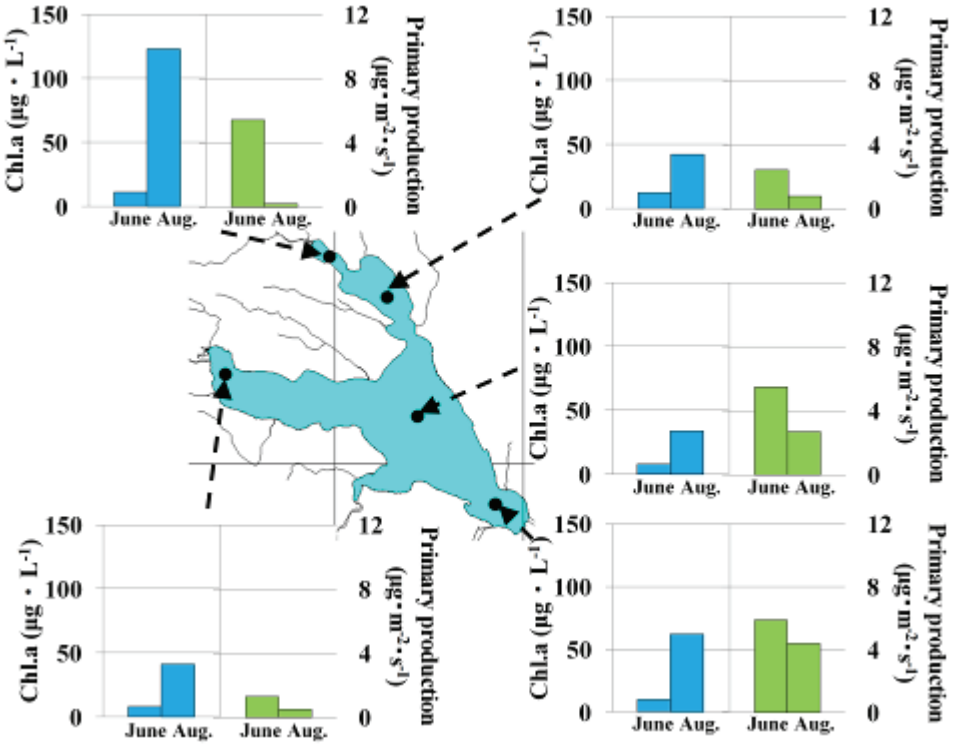


Fig. 4 Spatial variations in chlorophyll-a (Chl.a) concentration and primary production in Lake Kasumigaura (June and August, 2012).

We investigated the influence of the green tide formed by *Ulva* algal species on the ecological functions of Yatsu tidal flat, as compared with those at an adjacent control site, Sanbanze tidal flat. We developed a robust method to identify three independent *Ulva* species on the basis of a DNA marker, and we found that *Ulva ohnoi*, which is considered an invasive species, was the dominant species at Yatsu. *Ulva ohnoi* bloomed at Yatsu nearly all year long, the exception being in late summer, whereas it was not dominant at Sanbanze. We investigated the impacts of green tides on the ecological functions of the tidal flat. Both total species number and the amount of benthos were higher at Yatsu than at Sanbanze. The seasonal changes found at Yatsu seemed to be accompanied by changes in the biomass of *Ulva*. Furthermore, total phosphate and nitrogen levels in the sediment interstitial water were highly affected by the summer disappearance of *Ulva* at Yatsu. These results indicate that green tides have important ecological functions, such as supplying habitat for benthos and influencing the phosphate and nitrogen cycle.

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

In aquatic ecosystems, primary production is the production, by algae, of organic compounds from carbon dioxide. Almost all life in ecosystems is directly or indirectly reliant on primary production, because it forms the basis of the food chain. Hence, the rate of primary production, or primary productivity, is thought to be one of the factors restricting fish production and yield. Since 2012, we have been monitoring primary productivity in four dammed reservoirs in Thailand (Sirindhorn, Lampoa, Ubolratana, and Huai Luang reservoirs) and in the largest

freshwater lake in Southeast Asia, Tonle Sap in Cambodia, by using the stable carbon isotope (^{13}C) method to identify factors affecting the productivity of these man-made and natural water bodies.

We measured the depth profiles of primary productivity during the dry season (Fig. 5). Among the four reservoirs, surface layer primary productivity was highest in Huai Luang, which is more eutrophic than the other reservoirs. There was a significant positive correlation between the primary productivity per unit area and the total phosphorus level among the reservoirs. Tonle Sap was more eutrophic than the reservoirs. However, because the lake water contained a substantial amount of suspended solids and its transparency was very low (about 50 cm), the primary productivity of this lake fell precipitously at a depth of about 20 cm, although productivity was relatively high at the water surface. As a result, depth-integrated primary production was no higher in Tonle Sap than in the Thai reservoirs. From these observations, we concluded that primary productivity is constrained by low photosynthetically active radiation in Tonle Sap and by the phosphorus content in the Thai reservoirs.

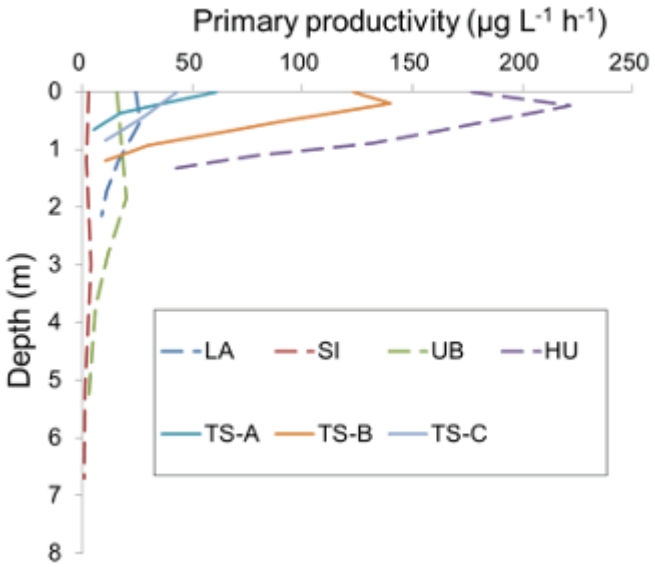


Fig. 5 Depth profiles of primary productivity in the Thai reservoirs in May 2012 and in Tonle Sap in February 2012. SI, Sirindhorn; UB, Ubolratana; LA, Lampoa; and HU, Huai Luang are the reservoirs. TS-A, TS-B, and TS-C are the upper, middle and lower stations, respectively, of Tonle Sap.

Annual fish yield per unit area was highest in Huai Luang Reservoir and lowest in Sirindhorn Reservoir; this followed the same order as primary productivity for these reservoirs, suggesting a strong positive correlation between primary production and fish production (Fig. 6). The considerably high fish yields estimated for Tonle Sap deviated to lie above the line of correlation owing to the lake's low primary productivity compared with those of some of the reservoirs (see above). Allochthonous input of organic matter from the floodplain surrounding the lake, or from the lake's tributaries, may play an important role in sustaining fish yields, as opposed to autochthonous primary production in the lake.

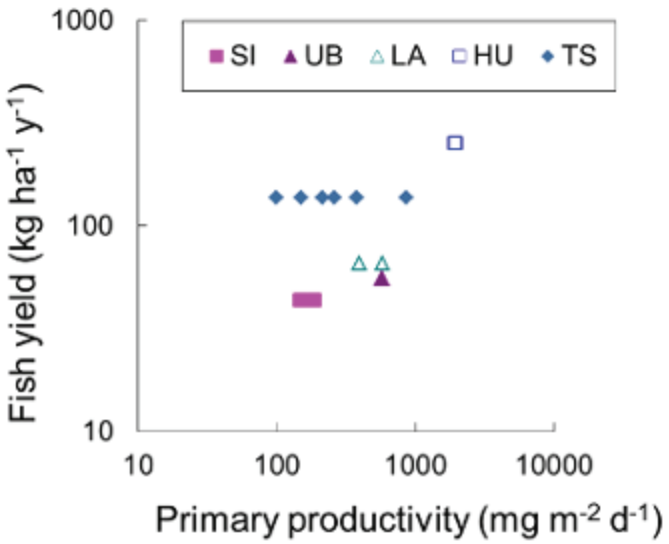


Fig. 6 Relationship between primary productivity and fish yield in the four reservoirs (SI, Sirindhorn; UB, Ubolratana; LA, Lampoa; and HU, Huai Luang) and three stations in Tonle Sap (TS). Multiple data points for the same reservoir and for the lake are primary productivity estimates in two different months in 2012.

III. Special Research

Influence of hydrogen sulfide in the sediment of a hyper-eutrophic coastal sea on benthic fauna and oxygen consumption (FY 2010–2012)

Coastal seas surrounded by urban areas have been suffering chronically from strong hypoxia resulting from eutrophication promoted by an enormous influx of anthropogenic macronutrients and the massive loss of benthic habitats through intensive reclamation. This has diminished the important function of these coastal seas as accumulators or degraders of excess organic matter in coastal ecosystems. Hypoxia promotes sulfide accumulation in sediments and has an adverse effect on benthic fauna. However, some bivalves are not very susceptible to hypoxia, suggesting that other factors may be causing this deterioration (Fig. 7). Hydrogen sulfide (H_2S) is very toxic to organisms and can be abundantly formed in marine sediments via sulfate reduction by bacteria under hypoxic conditions; it is therefore a principal factor in the impairment of benthic fauna. In Japan, the sulfide present in sediments has been so far determined to be acid volatile sulfide (AVS). It takes both free forms and iron-bound forms, the separate activities of which have not yet been fully evaluated. The free form of H_2S is much more chemically active and more toxic than the iron-bound one. Through field work in inner Tokyo Bay, we attempted to determine the relationship between the accumulation of free H_2S in sediments and the deterioration of benthic fauna, as well as the effect of free H_2S on oxygen consumption.

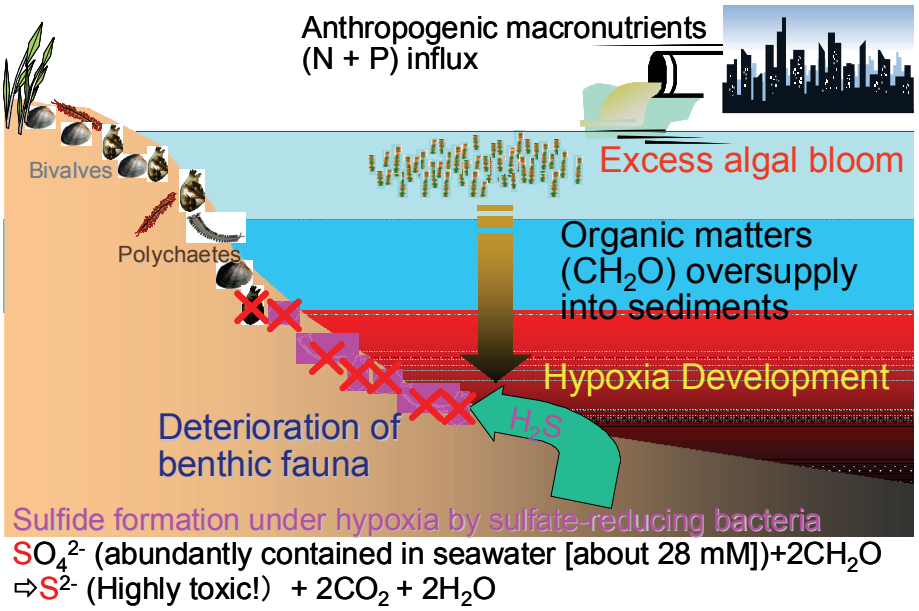


Fig. 7 Mechanism of benthic fauna deterioration through sulfide formation in sediments.

Accumulation of the free form of H_2S was greatest from late summer to autumn and declined in winter. In contrast, AVS levels did not show a distinct seasonal change (Fig. 8). The vertical profiles of free H_2S in core sediment samples showed that the highest concentration was 0.03 to 0.05 m from the surface (Fig. 9). The free form of H_2S was a more suitable index than low dissolved oxygen concentration in the bottom layer or AVS for explaining the magnitude of benthic fauna deterioration (Fig. 10).

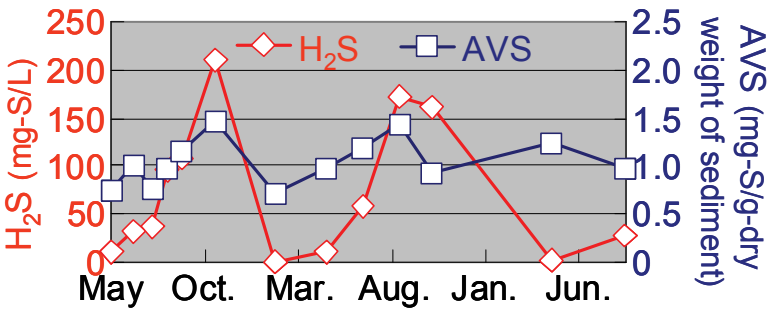


Fig. 8 Seasonal changes in acid volatile sulfide (AVS) and H_2S levels in the sediments of Tokyo Bay.

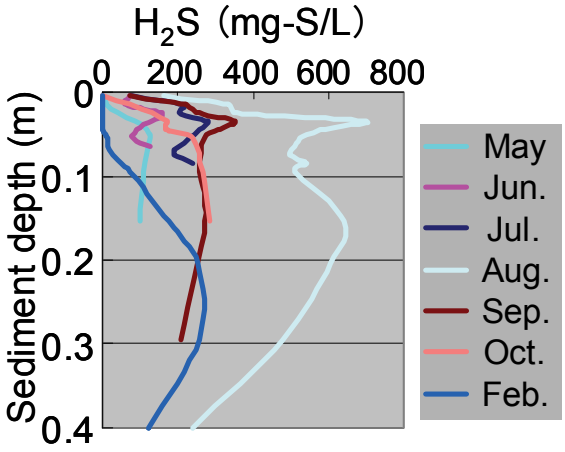


Fig. 9 Accumulation and vertical profile of H_2S in the sediments of Tokyo Bay.

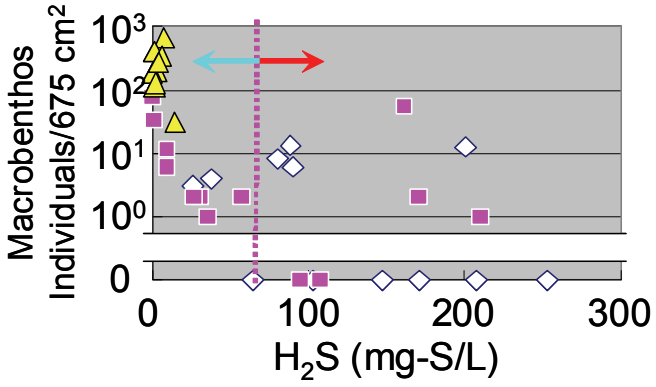


Fig. 10 Relationship between macrobenthos abundance and H_2S content of sediments at three stations in the inner part of Tokyo Bay. Sanmaizu (an water depth [wd] of 6 m, fine sand), yellow triangle; Tokyo light beacon (wd of 15 m, silt and clay), diamond; Chiba light beacon (wd of 12 m, silt and clay), pink square.

To a greater degree than factors such as organic matter content and benthic respiration, free H_2S that diffuses from the sediments through exogenous turbulence is likely to contribute to oxygen consumption. Our findings imply that the free form of H_2S is an important biogeochemical index of the status of sediments and for the management of coastal sea environments.

Study of the biogeochemical cycle of organic matter and its interrelationships with the microbial community in lacustrine environments (FY 2008–2011)

Recently, a long-term steady increase in dissolved organic matter (DOM) has been observed in many lakes and reservoirs all around the world. In Japan, the gradual accumulation of recalcitrant DOM in lake water presents a serious challenge for the ways in which lakes are managed for environmental and ecosystem protection and drinking-water quality.

In this study, we examined the interrelationships between the quantity and quality of DOM and microbial production in the shallow, eutrophic Lake Kasumigaura, the second-largest lake in Japan. 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 a three-dimensional lake model, we intended to quantify the contributions of several allochthonous and autochthonous sources to recalcitrant DOM in Lake Kasumigarua.

We found that bacterial biomarkers such as D-amino acids can be used to estimate bacterial contribution to the DOM pool in Lake Kasumigaura. Bacterially derived DOM accounted for 35% to 55% of the lake's DOM. The bacterially derived DOM was more resistant to microbial degradation than was the bulk DOM. The majority of recalcitrant DOM in Lake Kasumigaura is probably bacterially derived.

The lake model calculation and analysis using the long-term trend data during the period 2001–2007 yielded an interesting quantitative finding. At the center of the lake, the average contribution to recalcitrant DOM of rainwater was 0.6%, of river water, 67.5%, of sewage treatment plant effluent, 2.9%, of sediment release,

12.0%, and of water column production, 17.6% (Fig. 11). The autochthonous contribution (sediment release + water column production) accounted for about 30% and increased with the occurrence of cyanobacterial *Microcystis* water blooms. Our findings thus elucidated the importance of the autochthonous contribution to the lake's recalcitrant DOM.

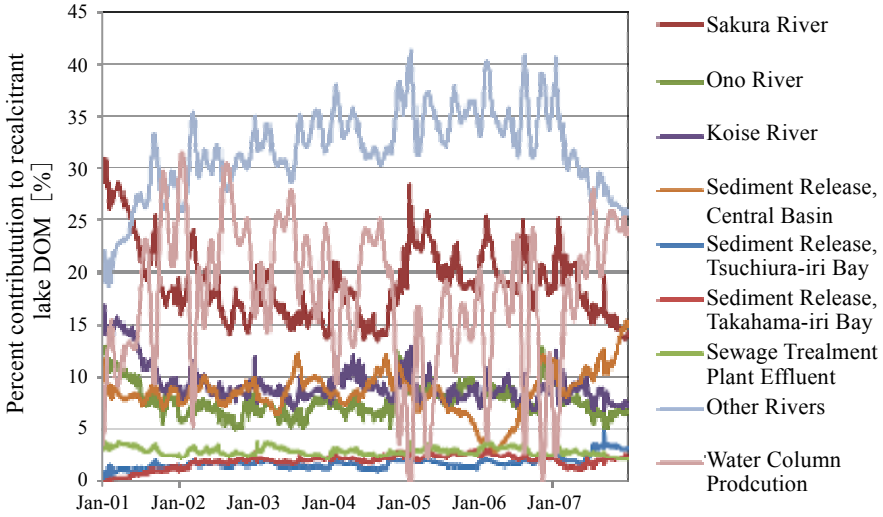


Fig. 11
Model-estimated percent contributions of allochthonous and autochthonous sources to recalcitrant dissolved organic matter (DOM) at the center of Lake Kasumigaura, 2001–2007.

Influences of the 2011 tsunami disaster on a brackish lagoon ecosystem (Gamo Lagoon, Sendai Bay) (FY 2011)

On 11 March 2011, a tsunami stuck the coast of northeastern Japan. We have started studying the tsunami-induced changes to the coastal environments and biological communities of the Tohoku region.

We conducted a series of surveys in a shallow brackish lagoon, Gamo Lagoon (Sendai City, Miyagi Prefecture), in 2011 and 2012. We compared the lagoon topography, vegetation, and macrozoobenthic community structure with available pre-tsunami data. The topography and vegetation were modified drastically by the tsunami; the lagoon surface decreased in 32% (from 17.3 to 11.8 ha), sand dune vegetation decreased by 99% (from 8.6 to 0.1 ha), and reed marsh decreased by 84% (from 7.8 to 1.2 ha). On the other hand, the tsunami created new azoic sand flats in the lagoon because of the marsh disappearance and sand deposition. Muddy organic-rich sediment was replaced with coarse sea sand, and the phytoplankton biomass in the water column declined sharply. These findings suggest that the lagoon has become less eutrophic. Improvement of the sediment and water quality should be one of the positive effects of the tsunami disaster (Fig. 12).

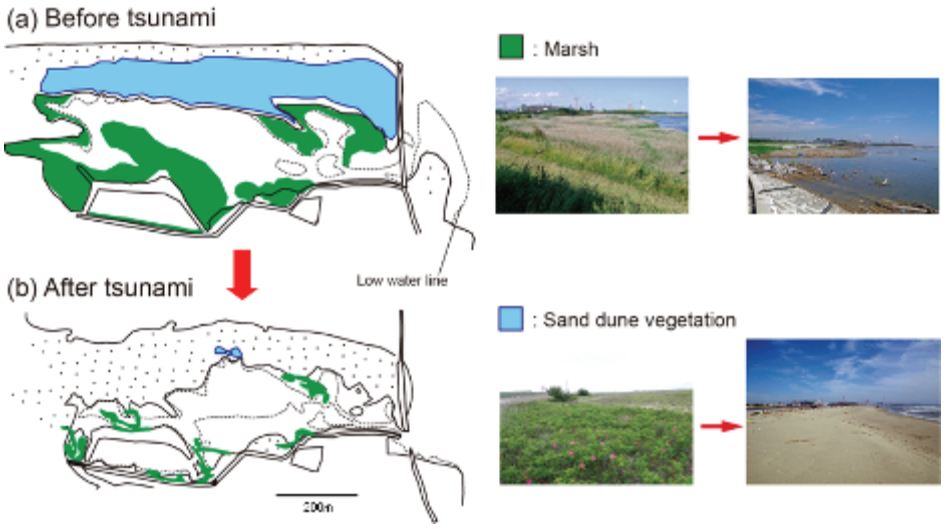


Fig. 12 Changes in topography and vegetation at Gamo Lagoon (Sendai, Miyagi Prefecture) after the 2011 tsunami.

Of 79 species of macrozoobenthos, 47 (especially bivalves) were absent or nearly wiped out. Temporary immigration of 12 marine species was also found after the tsunami, but most disappeared with decreasing salinity (i.e. recovery of the brackish environment). The improving sediment condition and the creation of azoic sand flats are allowing the rapid recovery and dominance of opportunistic species such as polychaetes and amphipods. Multivariate analyses (by non-metric multidimensional scaling) using 20 years of historical data revealed that the macrozoobenthic community structure recovered shortly after the tsunami. They also showed that the change was comparable with those that occurred during the 1990s as a result of saline regime shifts after reparian works in the estuary. These findings showed the rapid recovery potential of the macrozoobenthic community in estuarine habitats once the environment (e.g. water and sediment quality) has recovered (Fig. 13).

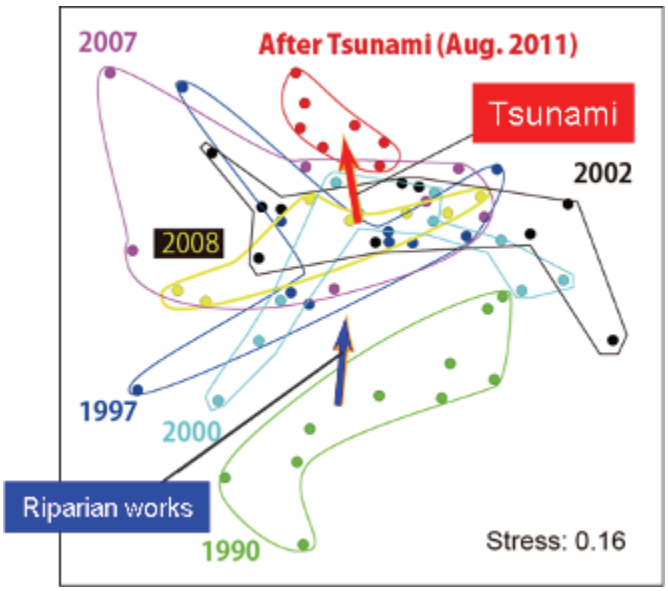
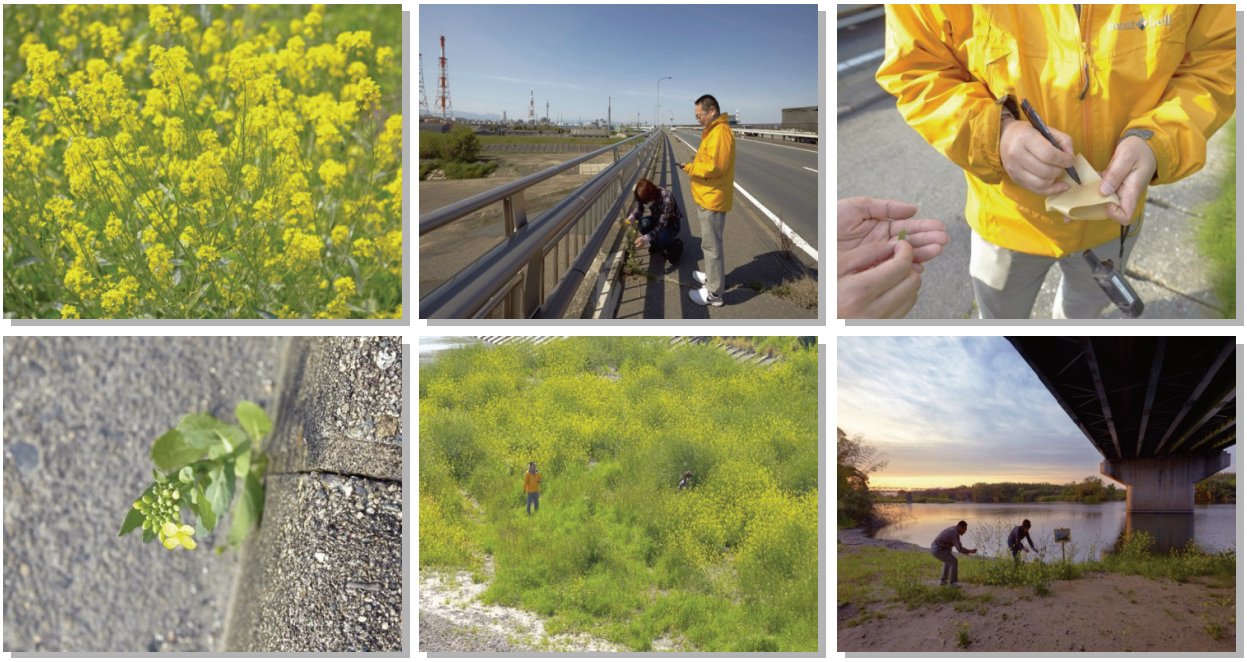


Fig. 13 Non-metric multidimensional scaling plot showing historical changes in the macrozoobenthic community structure in Gamo Lagoon from 1990 to 2011. Symbols of the same color indicate samples from the same year. Density data from 7 to 10 areas within the lagoon were averaged and square-rooted before analysis.

Center for Environmental Biology and Ecosystem Studies



Field work of long-term monitoring of the oilseed rapes

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 the Biodiversity Research Program, which is one of the five Priority Research Programs in place at the institute, 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, CEBES researchers are using competitive funds to conduct fundamental biodiversity and ecosystem conservation studies. We have also conducted research into the effects of the Great East Japan Earthquake on organisms and ecosystems.

In addition to research, CEBES conducts long-term monitoring of lake ecosystems and the distribution of genetically modified oilseed rapes at roadside sites. 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, make predictions of its future, and propose reliable and effective methods for its conservation on a scientific basis. Our tasks are to develop methods and protocols for monitoring the status of biodiversity at the genetic and landscape levels; assess the state of biodiversity on a broad scale and analyze scenarios for future prediction; and elucidate the effects of anthropogenic disturbances on biodiversity and find ways of managing these effects. The following are examples of our progress in FY 2012.

1. 1 DNA sequences as tools for biodiversity assessment

DNA sequences have become important sources for understanding biodiversity. It is possible to identify species by referring to databases of DNA sequences. Creating reliable databases based on both morphology and DNA techniques ("DNA barcoding") is of primary importance for biodiversity assessment. In general, DNA sequences are unique to each species but are not identical among individuals within each species because of small mutations. Theoretically, the

genetic divergence calculated from DNA sequences should be larger among species than within species.

We have conducted DNA barcoding for partial sequences of the COI (cytochrome *c* oxidase subunit I) gene of the Chironomidae, non-biting midges. In insects, this gene is suitable for detecting sequence variations at species level and is used as the standard gene for DNA barcoding. Larvae of the Chironomidae are aquatic and can be indicators of the status of aquatic ecosystems and water pollution. However, the difficulty in identifying species in this family from their appearance limits their utility as environmental indicators. We examined the genetic divergence within and among species of the genus *Chironomus*, which is characterized by a worldwide distribution and high abundance. In 50 *Chironomus* species identified by their morphologies, the average genetic divergences between and within species were 15% and 2%, respectively (Fig. 1).

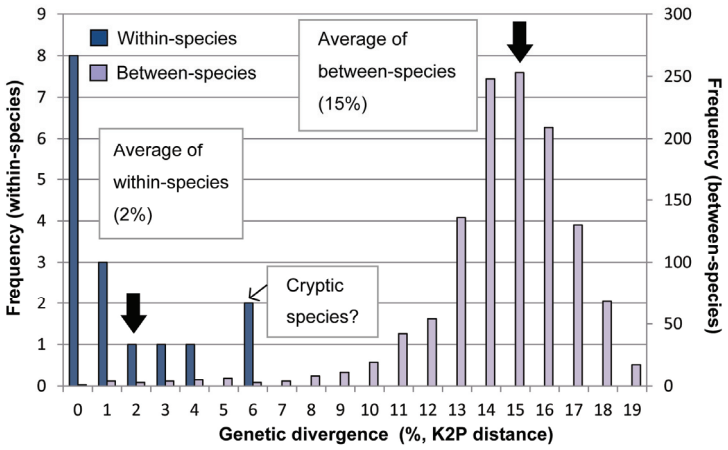


Fig. 1 Frequency distributions of average genetic divergences between and within species of *Chironomus*. Genetic divergences as the numbers of base substitutions estimated by using Kimura 2-parameter (K2P) model, were calculated for all combinations of the species available from our data and from the DNA Data Bank of Japan and were averaged for each species ("within- species" in the graph) or pair of species ("between-species").

Figure 1 shows that individuals with genetic divergences below 5% are expected to be identical species of *Chironomus*. This empirical value could be used to find and identify new and cryptic species of *Chironomus*.

1.2 Spatial prioritization of deer management to conserve endangered plants

Spatial allocation of management effort is essential to develop cost-effective strategies for biodiversity conservation. Computational optimization is a powerful tool for selecting a set of conservation sites that covers the maximum number of species under a given constraint, such as total budget. Recently, this method has been used to select effective conservation reserves worldwide. Although spatial conservation prioritization usually focuses on static systems in which species distribution and the threats to species do not vary with time, many factors that pose threats do in fact vary with time.

In Japan, the sika deer (*Cervus nippon*) has been expanding its range for the last several decades. Its feeding pressure has been posing a threat to plant species,

including endangered ones. Management of deer populations by culling and protection of plants by fencing are labor intensive. Prioritization of sites to be managed is crucial to achieve conservation success. We evaluated spatial priorities in deer management to conserve endangered plants today and in the future. We applied a heuristic algorithm to search a quasi-optimal set of priority areas by sequentially choosing those spatial units with the greatest number of plant species that had not yet been conserved. A spatial unit in this study was a cell about 10 × 10 km. We evaluated the minimum area required to conserve at least one population of each endangered plant species. The plants' distribution data were extracted from a database of threatened vascular plants in Japan.

The results showed that all of the populations of 48% of the endangered plant species would be at risk of being affected by deer feeding in 2103. However, 300 management-area cells were enough to conserve at least one population of all of the endangered plant species under quasi-optimal site selection (Fig. 2).

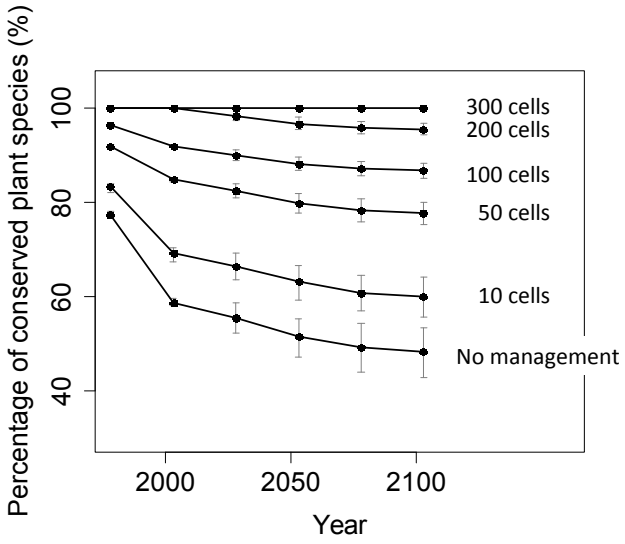


Fig. 2 Percentages of endangered plant species for which at least one population would be conserved from feeding pressure under various management efforts (i.e. numbers of managed cells). Error bars indicate 95% quantile.

Sites to be managed would expand to the northern part of Honshu, Japan's main island, by 2103 (Fig. 3). Although there were clumps of management sites in several regions, patterns of quasi-optimal management sites were scattered over Japan.

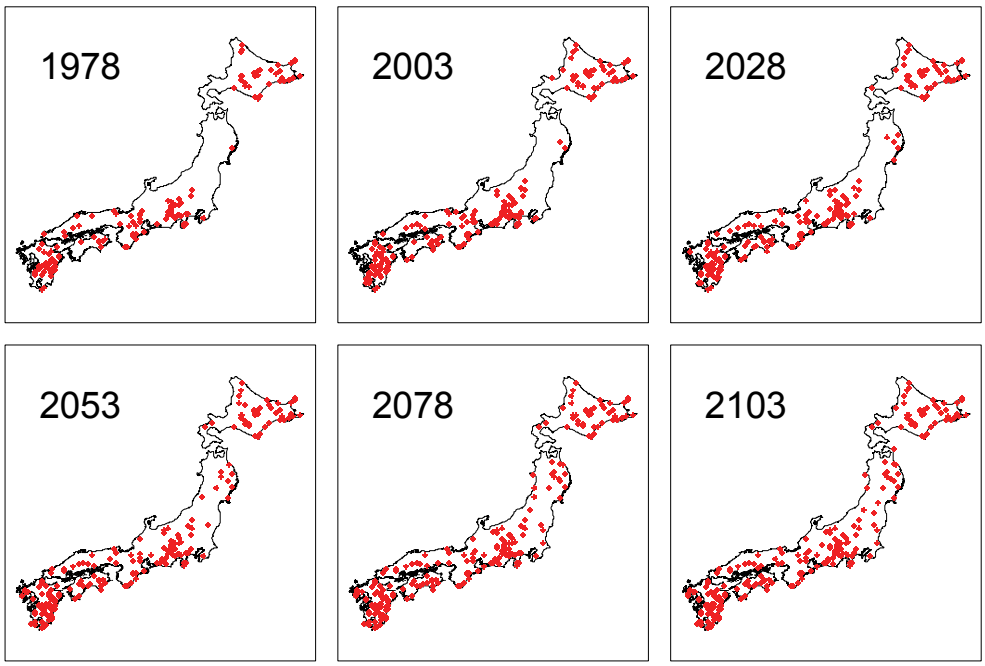


Fig. 3 Locations of selected deer-management sites (indicated by red dots) for conservation of at least one population of all of the endangered plant species.

1.3 Potential risk map for avian influenza A virus invading Japan

The original natural hosts of avian influenza virus are believed to have been ducks, shorebirds, and gulls. Low pathogenic avian influenza (LPAI) has been endemic among wild birds for a long time. In contrast, highly pathogenic avian influenza (HPAI) viruses of the H5N1 subtype (HPAI-H5N1) were first reported in poultry in the 1990s. Since then, epidemics of HPAI have become a major threat to poultry production and human health.

When cases of HPAI occurred in Japan in 2004, 2007, 2008, 2010, and 2011, it was noted that wild birds could carry and spread HPAI. In 2006 we started monitoring avian influenza virus (both LPAI and HPAI) in Japanese wild birds and migratory birds. We have created a potential avian influenza risk map based on the results of this monitoring.

The potential distribution of influenza-A-positive locations in 2010–2011 was characterized by environmental variables, including winter temperature, precipitation, duck population size, habitat abundance, size of urban areas, and farmed poultry density. We found that dabbling duck population, size of urban area, diving duck population, and altitude were associated with the occurrences of influenza A positive cases. Among these variables, dabbling duck population had the strongest effect on occurrence. We made a potential risk map from these results (Fig. 4). To explore the reliability of the risk map, we then compared the map indices and localities that were positive in 5 recent years for influenza A virus in wild birds. The points where wild birds were infected in 5 recent years were located in the high-risk areas on the map.

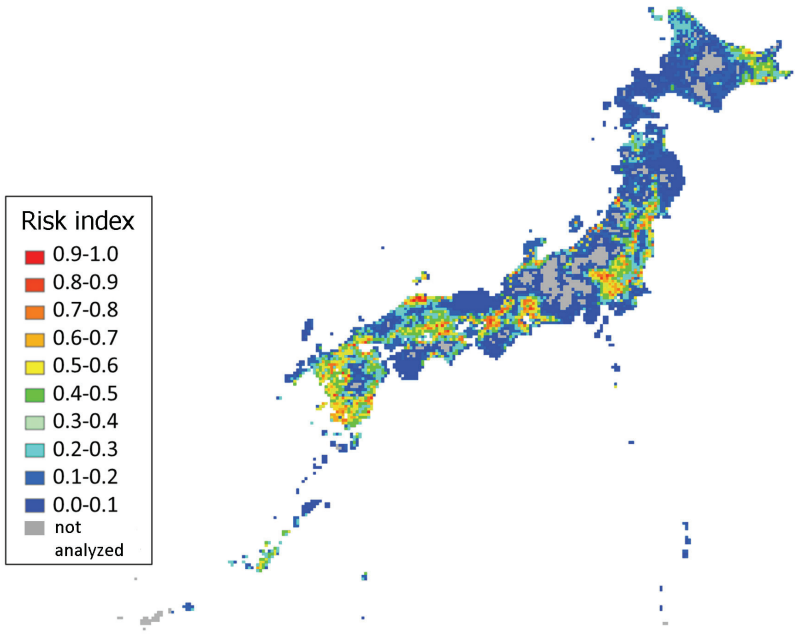


Fig. 4 Risk map for avian influenza (AI) in wild birds based on environmental characteristics of influenza- A-positive locations in 2010–2011.

The dabbling duck population in an area appeared to be the best indicator of high risk for the introduction of avian influenza from abroad. Priority monitoring localities for avian influenza carried by wild birds should be located in high-risk areas such as western Japan and along the Pacific coast. Poultry farms in these areas should increase their biosecurity to prevent vectors from introducing avian influenza.

2. Fundamental Research

2.1 IsoWeb: a Bayesian isotope mixing model for diet analysis of the whole food web

Quantitative description of food webs provides fundamental information for the understanding of population, community, and ecosystem dynamics. Recently, stable isotope mixing models have been used widely to quantify the dietary proportions of different food resources for a consumer of interest. We have proposed a novel mixing model (IsoWeb) that estimates all consumers' diet proportions in a food web by using stable isotope information. IsoWeb requires a topological description of the food web and the stable isotope signatures of all consumers and resources in the web. One merit of IsoWeb is that it takes into account variations in trophic enrichment factors among different consumer-resource links. Sensitivity analysis using realistic hypothetical food webs suggests that IsoWeb is applicable to a wide variety of food webs differing in number of species, connectance, sample size, and data variability. Sensitivity analysis based on real topological webs showed that IsoWeb can allow for a certain level of topological uncertainty in target food webs, including the

erroneous assumption of false links, the omission of existent links and species, and trophic aggregation into trophospecies. Moreover, we used an illustrative application to a real food web to demonstrate that IsoWeb can compare the plausibilities of using different candidate topologies for a web of interest. These results suggest that IsoWeb is a powerful tool for analyzing food-web structure from stable isotope data. We have provided program codes to implement IsoWeb, which should help in the efficient application.

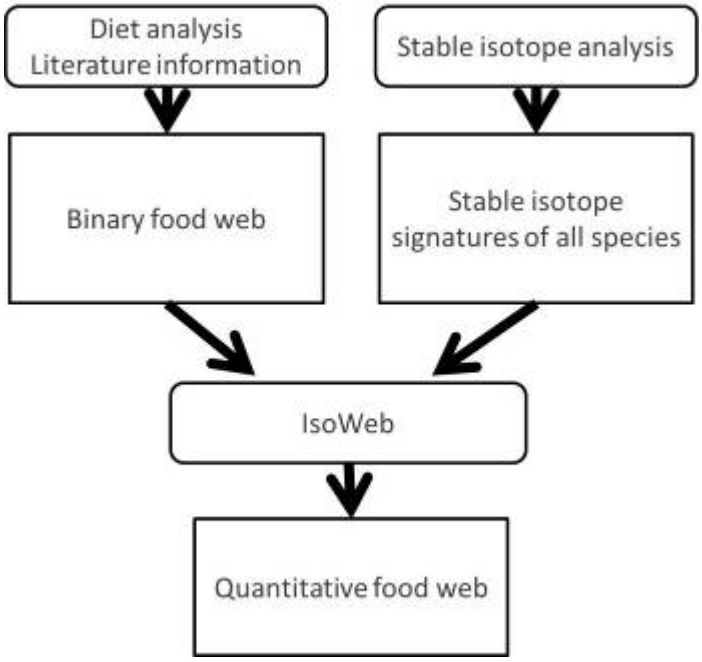


Fig. 5 Concept diagram of IsoWeb

2.2 Effects of introducing exotic and translocated species on the functional diversity of freshwater fish assemblages

The introduction of non-native species has largely modified the composition of biotas worldwide, creating novel assemblages that differ in composition or function from those in past systems. Although there is a growing need to understand and predict the effects of species introductions on ecosystem processes and functions on a large scale, the impact of introducing "translocated" species (i.e. species that are introduced within their native biogeographical zone but in localities where they have not historically occurred) has been much less widely considered.

The introduction of non-native freshwater fishes is an important component of global environmental change. In the last 100 years, the biogeography of Japanese strictly freshwater fishes has been reshuffled dramatically as a result of human-mediated introductions of non-native species. To explore the effects of these introductions of non-native species on ecosystem processes on a large scale, we used functional diversity (FD). This represents the value and range of

functional traits of the organisms present in a given ecosystem and is an important determinant of ecosystem processes.

By using comprehensive historical (1910s, i.e., before the fish introductions) and current (2010s, i.e., after the introductions) datasets of the Japanese freshwater fish faunas in 27 eco-regions in Japan, we investigated the spatiotemporal changes in FD and in the richness and composition of trait-based functional groups. We also compared the relative effects of exotic and translocated species on FD.

The introduction of both exotic and translocated species, increased the species richness 2.4 times, the FD 1.6 times, and the functional richness 2.1 times (Fig. 6). Functional group composition also changed, largely through the addition of new functional groups such as piscivores. The introduction of exotic species had a substantially greater effect size (the FD increase per species) than the introduction of translocated species, suggesting that exotic species are relatively functionally unique compared with native species. However, there was no difference in the overall net effects (total FD increase by all introduced species) between exotic and translocated species. Our findings suggest that the effects of exotic and translocated species on FD change depending on the species' functional uniqueness and richness.

We demonstrated that both exotic and translocated species may change FD and functional group composition, and that these changes in turn might have dramatic consequences for ecosystem processes. Our findings emphasize the need to improve the management of non-native species that does not consider translocated species.

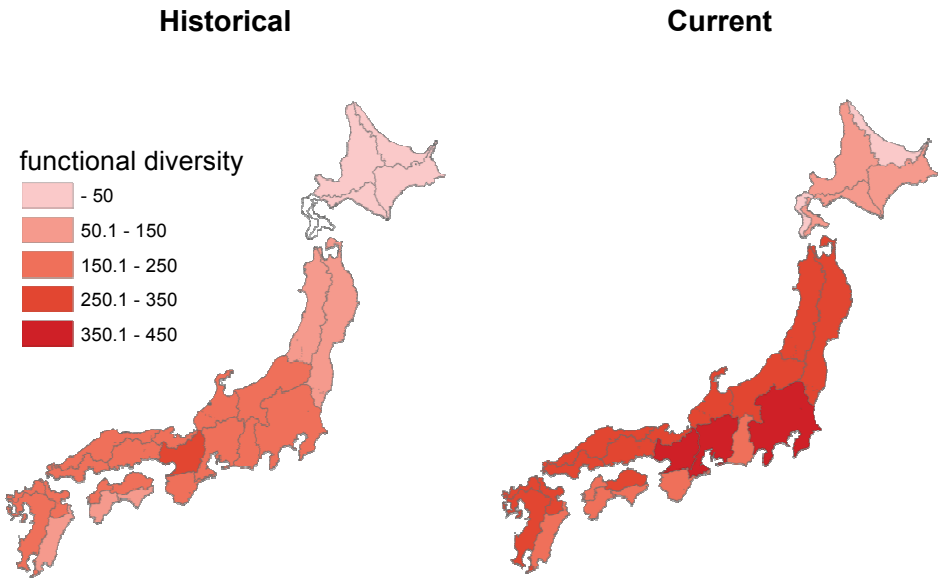


Fig. 6 Changes in functional diversity (FD) of freshwater fish assemblages in 27 eco-regions, from the historical (left panel) to the current (right panel) time period. Note that regions in which there is only one species are shown in white, because the presence of only one species does not permit the calculation of FD.

2.3 Long-term monitoring of distributions of herbicide-resistant oilseed rapes at roadside sites

More than 20 million tons of agricultural products is imported into Japan. About one-tenth of the tonnage is oilseed rape (*Brassica napus* L.) seeds. About half of the imported rapeseed has been genetically modified (GM) for resistance to herbicides. Some of these imported seeds are likely to be dispersed unintentionally during transport within Japan. Expansion of the population size of escaping GM crops has raised concerns about hybridization with wild relatives and introgression of transgenes into the genomes of wild plant populations.

Imported oilseed rape is discharged at several main ports (Kashima, Chiba, Yokohama, Shimizu, Nagoya, Yokkaichi, Sakai-Senboku, Kobe, Uno, Mizushima, Kita-Kyusyu, and Hakata) and transported to inland processing factories along several national main roads. Route 51 and Route 23 are the main transportation routes for imported oilseed rape from the Port of Kashima and Port of Yokkaichi to processing factories. The presence of herbicide-resistant individuals of oilseed rape was confirmed along these roads by our preliminary research. We have now performed more intensive fixed-route observations along these roads.

Our 3-year census of oilseed rapes growing along Route 23 indicated that the number of oilseed rapes growing in this area increased from early February and peaked in April (Fig. 7). Numbers were then suddenly reduced by regular weeding in June and were at their lowest in August. About 80% of the oilseed rapes growing in this area had a protein conferring the glyphosate resistance or gluphosinate resistance phenotype, and about 1% had both herbicide-resistance proteins, namely CP-4 EPSPS and PAT (Fig. 8). These findings suggest that a certain amount of outcrossing between the two types of herbicide-resistant GM oilseed rapes has occurred at these sites.

We also conducted a survey of oilseed rapes growing along Route 51, a major road in the Kanto district (Fig. 9). Our 8-year survey indicates that both the total number of oilseed rape plants and the number with GM traits decreased along Route 51 over the survey period. We found 304 oilseed rapes in this area, and 34 of them had herbicide resistance traits in 2010. By 2012 the number of plants had decreased to 28, and no plants with GM traits have been found in this area since 2011. Extensive repair of damage caused by the Great East Japan Earthquake has been conducted along this road, and this may have removed all of the GM oilseed rape seedlings.

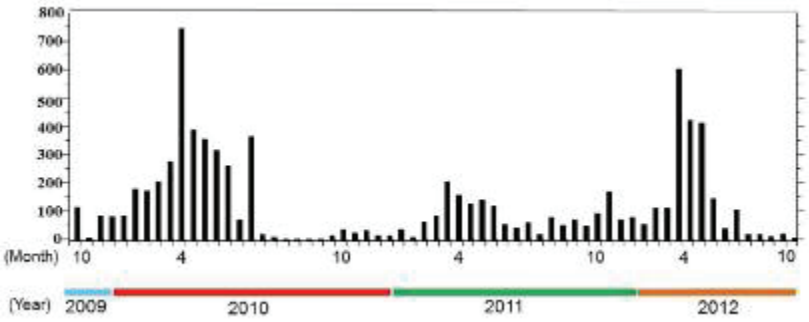


Fig. 7 Fluctuation in total number of oilseed rapes found along Route 23.

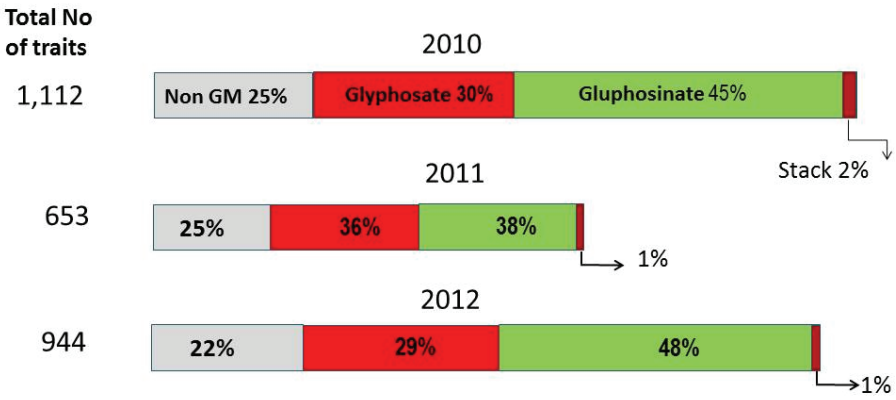


Fig. 8 Numbers of plants with genetically modified traits found along Route 23 during the 3-year survey. Red bars, population of glyphosate-resistant individuals; green bars, gluphosinate-resistant individuals. Brown bars, population of plants with both types of herbicide resistance ("Stack").

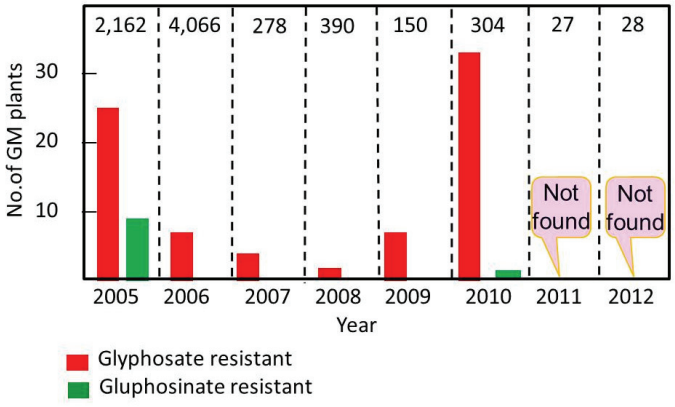


Fig. 9 Numbers of plants with genetically modified traits found along Route 51 during the 8-year survey. Numbers at the top of each panel indicate total numbers of oilseed rape plants found in the census area.

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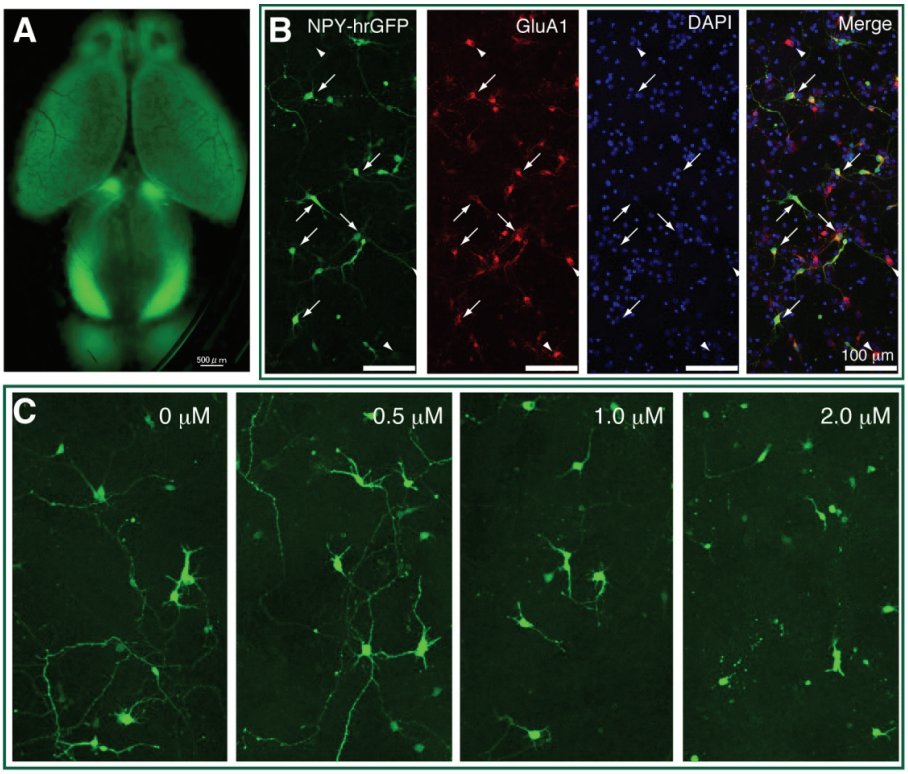


Evaluation of toxicity of environmental chemicals to neurite outgrowth on primary neurons obtained from transgenic mice expressing green fluorescence protein on this specific type of neuron.

A. Macroscopic view of brain from a transgenic mouse expressing a humanized Renilla green fluorescence protein (hrGFP) under the regulation of the neuropeptide Y (NPY) gene promoter (NPY-hrGFP). ***B.*** Immunocytochemistry of the AMPA receptor GluA1 subunit, which is closely associated with neurite elongation, in NPY-hrGFP neurons. Green indicates hrGFP-tagged NPY neurons. Red indicates GluA1 immunoreactivity. Blue indicates 4′,6-diamidino-2-phenylindole (DAPI), which shows the nuclei. Arrows indicate NPY-hrGFP- and GluA1-double-positive cells, and arrowheads indicate GluA1-single-positive cells. Most of the NPY-hrGFP neurons shown here exhibit GluA1 immunoreactivity. **C.** Morphology of NPY-hrGFP neurons treated with 0, 0.5, 1, or 2 μM $NaAsO_2$ (sodium arsenite) from days *in vitro* 2 to 4. Neurite length was markedly decreased at a concentration of 1 μM, and the decrease was even more marked at 2 μM.

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 environmental factors and the mechanisms underlying them, focusing primarily on fetuses, children, and vulnerable populations.

We therefore aim to experimentally investigate and assess the health impacts of environmental factors and their modes of action, develop a simple and fast exposure and impact assessment system, and conduct epidemiological surveys and studies to identify 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 this 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 indexes 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 future 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 more efficient and accurate exposure assessment.

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

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

- 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 2012 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 following intratracheal exposure to diisononyl phthalate (DINP) in an asthmatic mouse model. Combined treatment with DINP and ovalbumin (OVA) tended to increase the numbers of inflammatory cells in bronchoalveolar lavage fluid compared with OVA treatment alone in a dose-dependent manner, but the differences were not significant (Fig. 1A). In local lymph nodes, expression of antigen-presenting cell markers in the DINP+OVA groups significantly increased compared with those in the OVA group (Fig. 1C), and it tended to increase total cell numbers (Fig. 1B), cell proliferation, and Th2 cytokine production. DINP exposure did not affect the levels of expression of neuroimmune biomarkers in

the hypothalamus in our asthmatic mouse model. These results suggest that the impact of intratracheal exposure to DINP on allergic asthma might be weak.

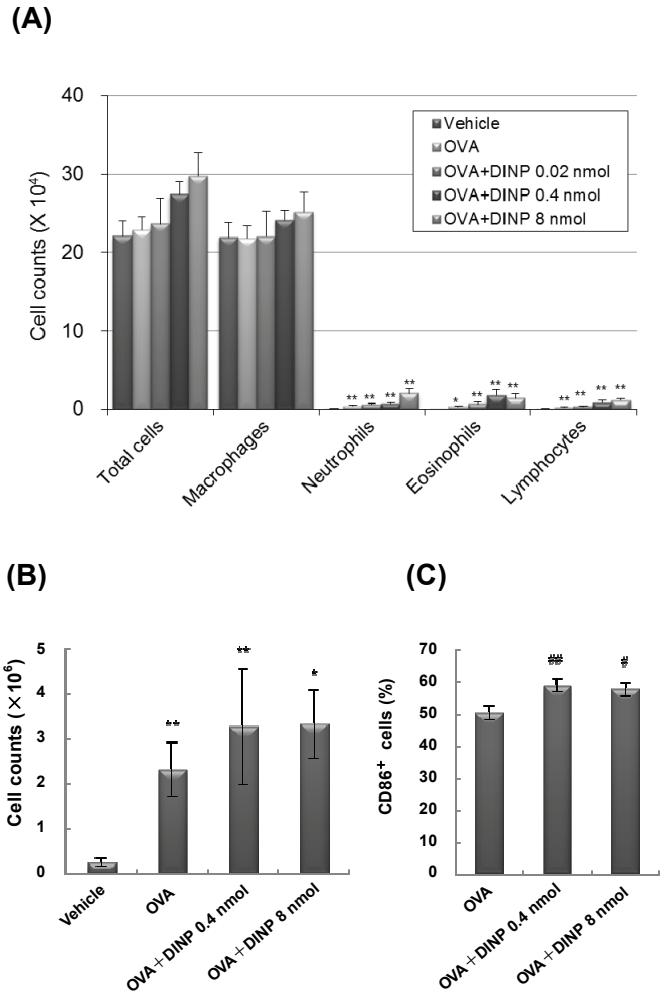


Fig. 1 Cellular profiles in bronchoalveolar lavage fluid and lung local lymph nodes following exposure to diisononyl phthalate (DINP) in a murine model of allergic asthma.
(A) Differential cell counts in bronchoalveolar lavage fluid. Data are means ± SE (n = 11–13; *P < 0.05, **P < 0.01 vs. vehicle group).
(B) Total cell numbers in local lymph nodes. Data are means ± SE (n = 6–8; *P < 0.05, **P < 0.01 vs. vehicle group).
(C) Expression of CD86, an antigen-presenting cell activation marker, in local lymph node cells. Data are means ± SE (n = 3 or 4; #P < 0.05, ##P < 0.01 vs. OVA group).

We investigated the effects of exposure to polycyclic aromatic hydrocarbon derivatives on bronchial epithelial cells *in vitro*. 9,10-phenanthraquinone and 1-aminopyrene stimulated intracellular signaling pathways, including phosphorylation of the epidermal growth factor receptor, in bronchial epithelial cells. This stimulation activated transcriptional factors associated with inflammatory proteins that may have toxicological and inflammatory effects.

We also investigated the effects of acute single intranasal administration of secondary organic aerosol (SOA) on the expression of various biomarkers in the brain and lung of male BALB/c mice. We generated the SOA by adding ozone (O_3) to diesel exhaust particles (DEP). Eight-week-old male BALB/c mice were given DEP or DEP+O_3 (SOA) (50 μg 50 μL^{-1} $mouse^{-1}$) intranasally. Twenty-four hours after acute single exposure to SOA, the olfactory bulb, hippocampus, and lungs were collected from all mice and expression of the mRNAs of neurological and immunological biomarkers was examined by using real-time RT-PCR analysis and histological examination. We found that expression of the mRNAs of

IL-1β (interleukin-1-beta), NF-κB (nuclear factor kappa-light-chain-enhancer of activated B cells), and BDNF (brain-derived neurotrophic factor) was significantly increased in the lungs of mice exposed to SOA (Fig. 2), but not in the brains. Our results clearly indicate that SOA induces inflammatory responses in the lung by modulating proinflammatory cytokines, transcription factors, and inflammation-responsive neurotrophins.

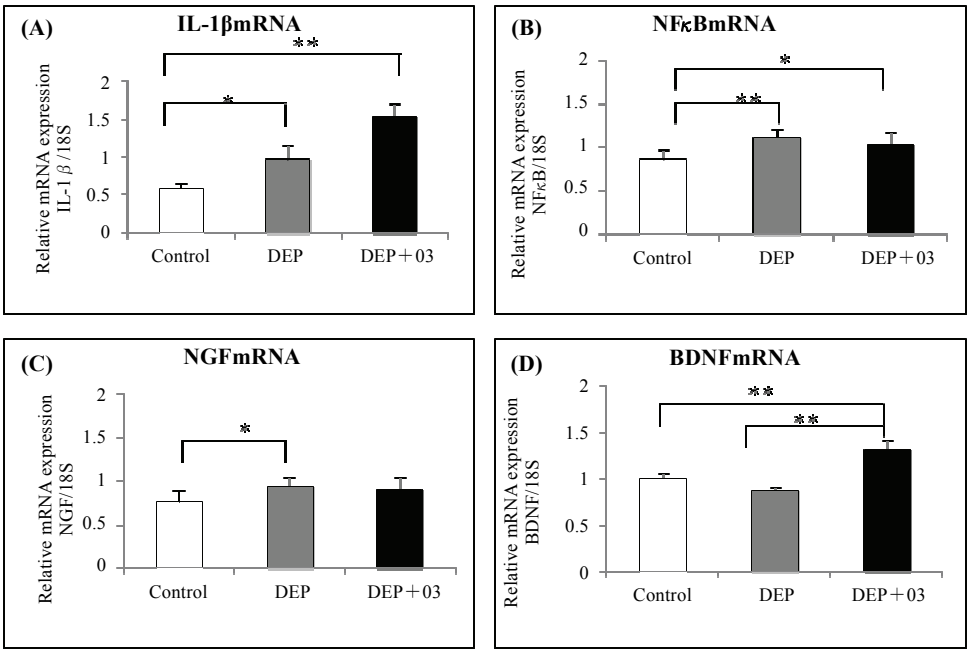


Fig. 2 Expression level of a proinflammatory cytokine, a transcription factor and neurotrophins in the lung of BALB/c male mice. Relative mRNA expression of (A) IL1-β, (B) NFκB, (C) NGF, and (D) BDNF in the lung of the control, DEP and DEP + O_3.

In the **Molecular Toxicology Section**, we have been studying the effects of environmental chemicals on biological and physiological functions and molecular mechanisms. Our recent focus has been on arsenic, because naturally occurring inorganic arsenic has been causing serious health problems, including cancer, in many areas of the world. The central nervous system, energy metabolism, and the immune system have emerged as targets of arsenic.

Prenatal arsenite exposure of mice increases the incidence of hepatic tumors in adult male offspring. Our study this year demonstrated that prenatal arsenite exposure particularly increased the occurrence of hepatic tumors with a C61A mutation in the oncogene Ha-*ras*. C61A mutation activates Ha-ras and induces the expression of downstream target genes involved in tumor promotion. We detected upregulated expression of these downstream target genes in the tumors of mice prenatally exposed to arsenic, supporting the notion that Ha-*ras* mutation caused by prenatal arsenic exposure is a pivotal factor in promoting tumors.

We performed both *in vivo* and *in vitro* animal experiments to investigate the mechanism by which prenatal exposure to environmental chemicals adversely affects behavior and energy metabolism. In our *in vivo* model, by using IntelliCage (NewBehavior AG, Zurich, Switzerland) we found that prenatal

exposure of mice to arsenite impairs learning behavior in a complex task paradigm. In addition, mice exposed to arsenite during gestation exhibited late-onset metabolic dysfunction. In our *in vitro* model, we established primary cultures of neurons obtained from perinatal mouse brain and found that neuritogenesis of primary neurons was impaired by exposure to arsenite. Suppression of AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid) receptor GluA1 expression by arsenite seems at least partly responsible for this neurite growth suppression.

We also studied the molecular mechanism of arsenic-induced immune suppression. Our previous study showed that arsenite induces cell-cycle arrest at G0/G1 by suppressing the expression of E2F-target genes *in vivo* and *in vitro*. Our study this year demonstrated that arsenite accumulates the retinoblastoma family protein p130, the regulatory molecule of E2F. We further revealed that arsenite inhibits phosphorylation/ubiquitin-dependent proteasome degradation of p130 by a novel mechanism, namely the induction of the cyclin-dependent kinase inhibitor $p16^{INK4a}$.

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.

- We are involved in a project to assess the health impact of climate change in the Kanto area. By examining emergency ambulance dispatch data, we characterized the effects of hot temperatures on the occurrence of heatstroke. These results will be used to estimate the future health impacts of climate change.

- In 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 death.

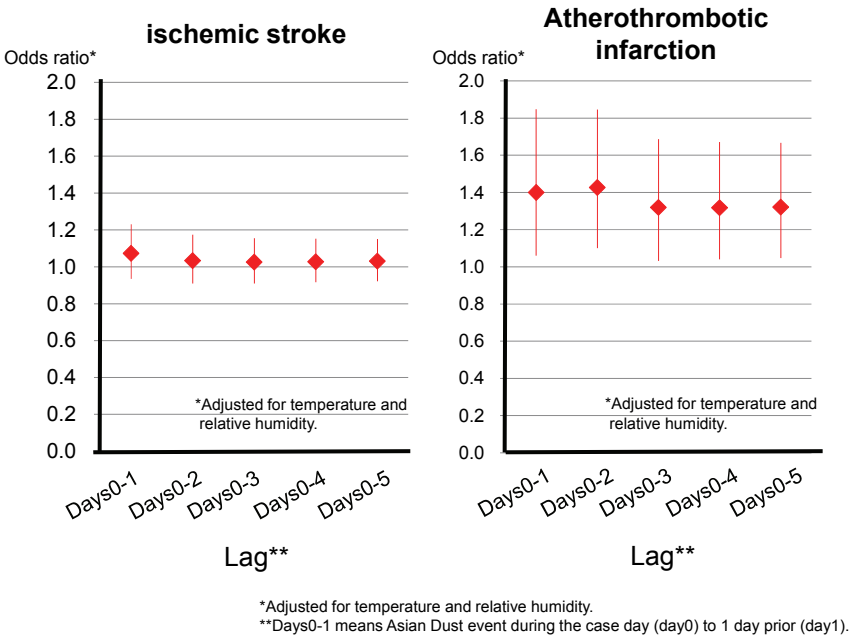
- Our current focus includes the health effects of long-range-transported air pollutants and of local air pollution. We found an increased risk of cardiovascular diseases—particularly atherothrombotic infarction (Fig. 3) and acute myocardial infarction—in Fukuoka during Asian Dust events.

- Health effects of long-term exposure to particulate matter (PM) are a focus of our research. We used data from the above-mentioned a cohort study to examine the associations between long-term exposure to PM and the risk of cardiovascular diseases and lung cancer (Fig. 4).

- We performed a PM exposure assessment. We compared the annual mean PM concentrations at fixed sites with PM concentrations at individual sites. These

results are important in allowing researchers to estimate the effects of PM measurement errors.

- We intend to upgrade our assessment methods for epidemiological health impacts and the biostatistical methods used to evaluate the growth and development of children. We also intend to extend the application of biostatistical methods to situations in which both exposure and outcome are repeatedly measured.



*Adjusted for temperature and relative humidity.
**Days0-1 means Asian Dust event during the case day (day0) to 1 day prior (day1).

Fig. 3 Association between Asian Dust and the incidence of ischemic stroke and atherothrombotic infarction

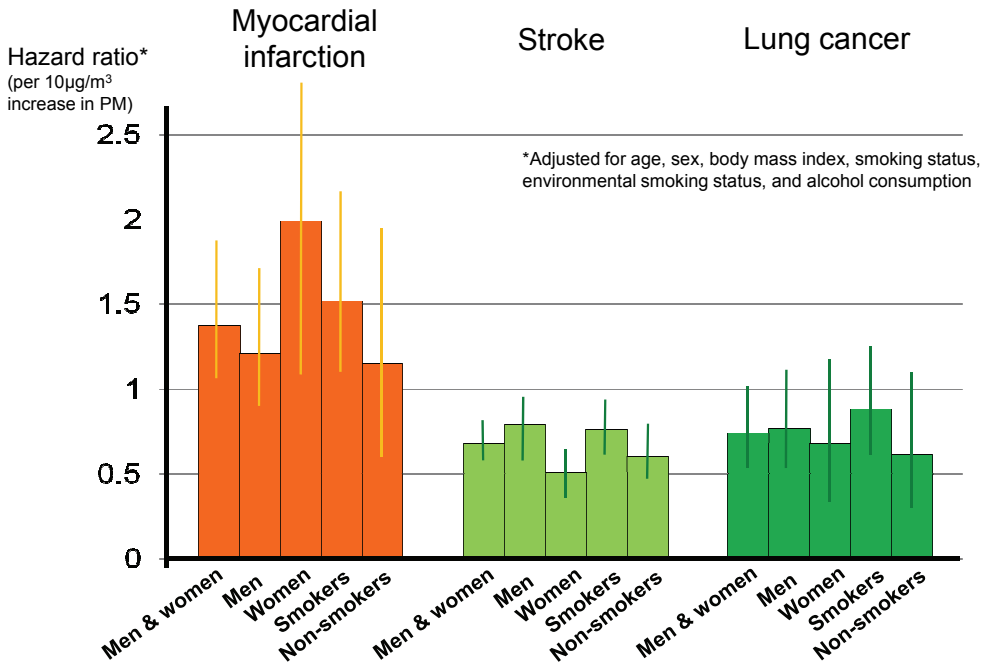


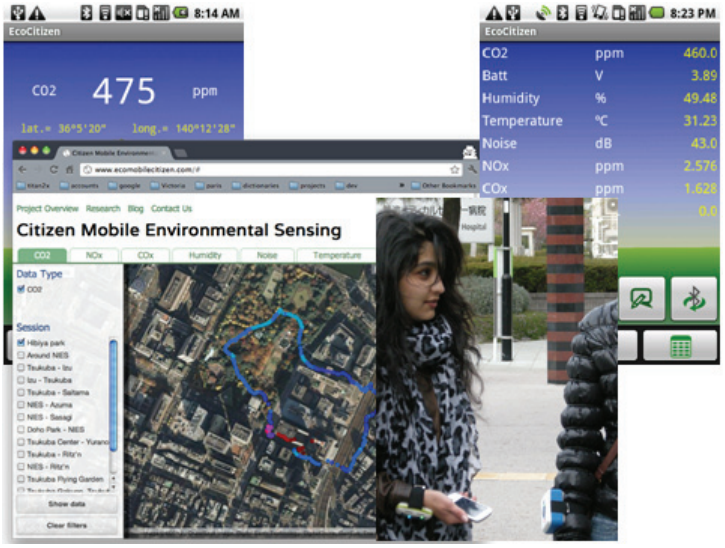
Fig. 4 Associations between particulate matter (PM) and the incidence of myocardial infarction, stroke, and lung cancer

The **Integrated Health Risk Assessment Section** conducts research that bridges the exposure sciences 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; the development and application of methods for high-throughput targeted and non-targeted analyses of environmental and biological samples; and exposure assessment using mathematical models. We work with a number of national collaborators, as well as with multinational and multidisciplinary research teams that include the US Environmental Protection Agency, EU partners, and Asian institutions. The integrated exposure assessment aims to develop a standardized mode-of-action-based toolkit for evaluating environmental samples such as wastewater effluent and surface water samples, which can ultimately be used for formulating emergency responses. For better organization of the research, the first international workshop on integrated exposure and effect analysis was held in September in Kumamoto. The workshop was funded by NIES and gathered over 50 researchers from North America, the EU, and Asian countries. Our field nutritional survey has been completed, and the data have been assessed to generate a draft FFQ. Under a collaborative research agreement with a Japanese analytical instrument vendor, a half a dozen high-throughput analytical methods are being developed; they will be applied to JECS and its pilot study.

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. 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. Recruitment started in 2011 and has now entered its third and final year; the number of participants enrolled now exceeds 65 000. The number of biological samples collected from the participants exceeds 200 000.

Center for Social and Environmental Systems Research

Delegates successfully completed the negotiation of a new global treaty on mercury: the Minamata Convention on Mercury.



Citizen Mobile Environmental Sensing

The Center for Social and Environmental Systems Research targets linkages between human activities and the natural environment in order to identify 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 such as 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 methodologies and applications relating to environmental conservation, including local goal-setting of environmental policies, and on the prediction and assessment of climate change impacts.
3. The **Integrated Assessment Section** develops integrated environment–economy models to assess environmental policies, such as those on global warming mitigation and adaptation, and sustainable development policies.
4. The **Sustainable Social Systems Section** studies sustainable futures for our society (i.e. a low-carbon society, LCS) and ways of achieving such a society in the long term without harming our economy.
5. The **Eco-City System Research Section** analyzes urban and regional environmental options such as low-carbon cities and sustainable transportation systems.

Our main research outcomes in FY 2012 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 taxing and emissions trading. We are also analyzing the environmental policy decision-making processes used by various countries and investigating the possibility of international cooperation on global environmental conservation.

(1) Study of policies for reducing fluorinated gas emissions at an international level

Chlorofluorocarbons (CFCs) and alternative substances such as hydrochlorofluorocarbons (HCFCs) pose interrelated environmental problems, because they act as both ozone-depleting substances and greenhouse gases (GHGs). However, the relevant international agreements constitute separate environmental regimes, namely an ozone regime and a climate regime. Complicating matters, the ozone regime regulates the production and

consumption of CFCs and HCFCs, whereas the climate regime regulates the emission of hydrofluorocarbons (HFCs), which are alternatives to CFCs and HCFCs. These separate regimes are obstacles to efforts to address the environmental impacts of these substances. We suggest that both the ozone and climate regimes should deal with all of these substances and should target more stages of the substances' life cycles. We also think that the existing treaties need to be amended accordingly.

(2) Study of the perceived cost of flood damage 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 cost of 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$1,400]), and the perceived cost of flood damage was estimated to be 1,196,209 yen/m^2 (approximately US$11,700/$m^2$). This estimate was larger than the one produced by the Tokyo Metropolitan Government, indicating that the cost of indirect damage is likely to be much higher than the direct damage cost (i.e. the cost estimate based on physical damage alone). On the basis of this result, we are mapping future flood damage so as to evaluate adaptation policies.

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 methodologies of understanding and assessing regional environments. We are also investigating the current status of public environmental awareness and the promotion of voluntary action by individuals.

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

As part of a move by society to change from a free plastic bag system to a fee-based system, as suggested by the Containers and Packaging Recycling Law, some local governments have introduced policies based on this law to local supermarkets. Convenience stores, however, have had a great deal of difficulty in reducing the consumption of plastic bags, because speed and convenience are important in their commercial system. The purpose of this study was to find clues to reducing plastic bag use in convenience stores. We conducted questionnaires in

three cooperative stores and analyzed the data collected. We specified nine types of shopping in terms of the types and quantities of goods purchased. We then identified the consumption of plastic bags for each type of shopping. For each type, we were able to suggest ways of reducing the consumption of plastic bags.

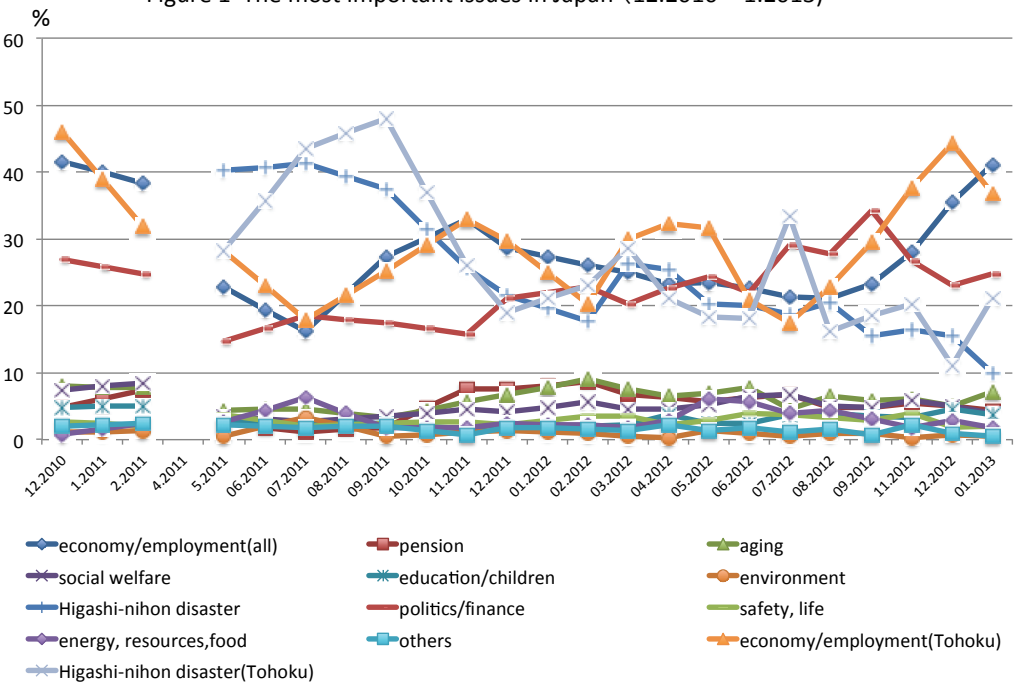
(2) Study of national trends in public interest in environmental issues

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 are at least 20 years old. 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 of Japan's most important issues, with special reference to the Tohoku region, from December 2010 to January 2013. Before the earthquake (December 2010 to February 2011), "economy/employment" was the most important issue both nationally and in the Tohoku region, followed by "politics/finance." In March and April 2011 we were unable to perform surveys. In May 2011, the most important issue was the earthquake, including the accident at the nuclear power plant. Interestingly, in the first 3 months (from May to July 2011), the rate of "the earthquake" response nationwide was higher than that in the Tohoku region, which was directly affected by the earthquake. Summer 2011 saw a peak in "the earthquake" response in the Tohoku region, no doubt because of mass media coverage of radioactive contamination of agricultural products from southern Tohoku and the northern Kanto region. People in the agricultural and related sectors suffered deeply from the damage caused by a dramatic decrease in the sales of these products. After summer 2012, the economies of both the nation and the Tohoku region were depressed.

Fig. 1 Changes in public perception and mass media coverage from December 2010 to January 2013, with special reference to the Tohoku region

Figure 1 The most important issues in Japan（12.2010～1.2013）



(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 the 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 (unitless and ranging from 0 to 1) changed with changes in the red-green-blue balance and were 1.0 (white), 1.0 (yellow), 0.9 (gray), 0.8 (red), 0.7 (blue), 0.6 (green), 0.4 (purple), 0.4 (dark green), and 0.1 (black). In the early morning time span, the order of the colors in terms of observed surface temperatures was nearly exactly the reverse order of the color brightness values. Brightness is therefore an important determinant of solar 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 difference decreased in the afternoon. Reflection performance in the near-infrared band is also an important determinant of surface temperature.

(4) Combined effects of building materials and outdoor physical conditions on the thermal environment

Building surfaces have a huge influence on both indoor and outdoor thermal environments. Building surfaces have many parameters that influence surface heat storage and emission, including color, pigment, surface roughness, albedo, size, and building orientation. Selection of proper materials can help to mitigate the heat island effect, namely the increase effect in warmth of cities compared with their surrounding rural areas, decrease the electricity consumption of buildings, and improve outdoor thermal comfort.

Building surfaces receive both direct solar radiation and multiple forms of radiation reflected between buildings and the ground surface. Latent heat and long-wave radiation are emitted from the surfaces to the atmosphere. Emission of this heat produces a strong buoyancy force close to the building surface. This thermally induced flow affects the flow field and thus affects the outdoor thermal environment. Different surface temperatures cause different buoyancy flows and thus changes in airflow patterns in the vicinity of buildings.

Our experimental chamber (Fig. 2) uses different building models to represent city blocks. Building roofs and windows are made of insulated (coated with nanomaterials) or non-insulated materials. We use scale models to characterize the thermo-physical properties of the different insulating materials. We also clarify how different building materials influence outdoor thermal environments and flow fields; determine how fluctuating solar radiation influences building materials and eventually influences outdoor thermal environments; and obtain optimum height-to-width ratios for the spaces between buildings with different surface materials. We also intend to use a computational fluid dynamics simulation to investigate how, and to what extent, the various parameters affect outdoor thermal comfort. The results will provide guidance for future application of building technologies into urban design and planning.

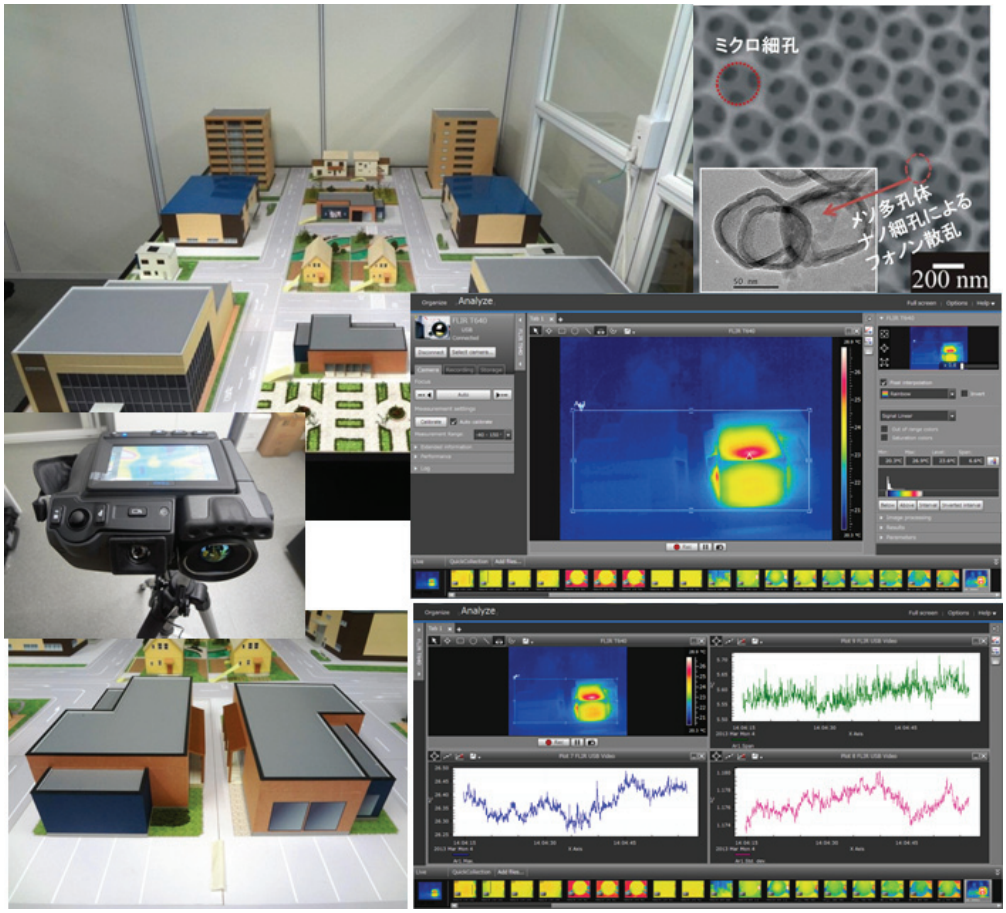


Fig. 2 Scale models are used to represent buildings. The roofs of these model buildings are coated with nanomaterials. An infrared camera is used to observe the changes in temperature outside the model buildings. The system can provide thermal images and can plot the temperatures at certain spots and the maximum, minimum, and average temperatures of a certain area.

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 the assessment of sustainable development issues. The following topics were our main activities in 2012.

(1) Assessment of GHG emission-reduction targets for 2020–2030 in Japan

After the Higashi-Nihon Earthquake and Fukushima Dai-ichi Nuclear Power Plant Accident, discussions of the GHG emission reduction targets for Japan for the period 2020 and 2030 (Fig. 3) proceeded with the restarting of the nuclear power plant. We used the AIM/Enduse model, which recommends the selection of technologies to achieve the targets, and the AIM/CGE model, which represents the economic impact of GHG emission reduction, to provide numerical results to the Central Environmental Council of the Ministry of the Environment and the

Energy and Environment Council. The past target, which was a 25% reduction by 2020 compared with emissions in 1990, will not be achievable by domestic efforts alone. In 2030, the emission reduction will be in the range of 20% to 35% if maximum countermeasures are introduced up to that time. The corresponding gross domestic product (GDP) loss in 2030 will be 0.6% to 2.0% compared with the reference case.

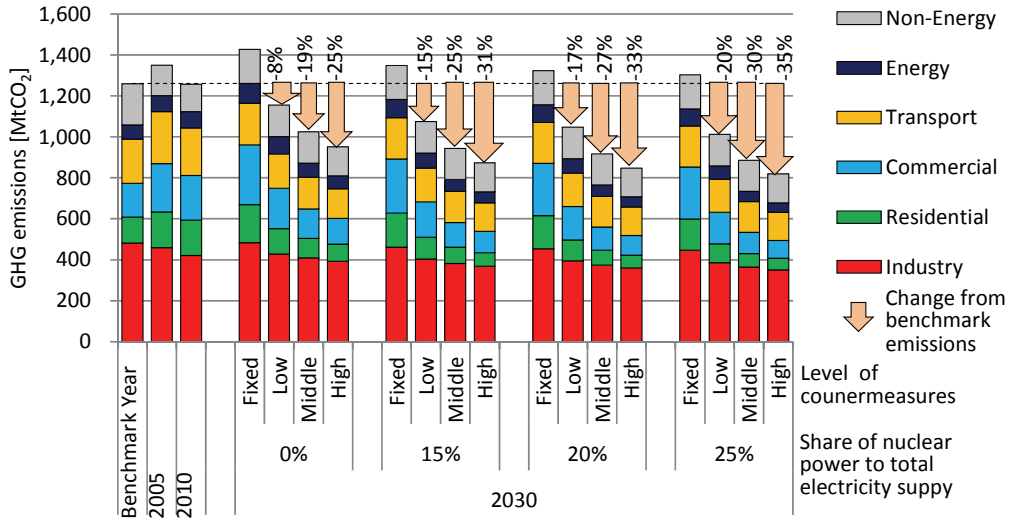


Fig. 3 Sectoral GHG emissions in Japan in 2030 (low-economic-growth scenario)

(2) Agriculture modeling comparison

We used a new scenario framework to assess the contributions of socioeconomic and climate conditions and adaptation measures to the impacts of climate change on food consumption and risk of hunger through changes in crop yield. We combined a global computable general equilibrium model and a crop model (M-GAEZ), and we estimated the climate change impacts through 2050 on the basis of future assumptions of socioeconomic and climate conditions and adaptation measures (changes in crop varieties and planting dates). To account for uncertainties in these factors, we used three SSPs (shared socioeconomic pathways) as socioeconomic conditions, four RCPs (representative concentration pathways) as GHG emissions constraints, and 12 GCMs (general circulation models) to estimate climate conditions (Fig. 4). Population, GDP, and adaptation measures were modeled as social and environmental factors that strongly affect food supply and demand. Socioeconomic conditions had a greater impact than climate conditions on the risk of hunger, at least through 2050, but climate change was projected to have notable impacts, even under the strong emission mitigation scenarios. The impact on hunger risk varied across regions because of variation in the levels of food consumption and climate change impacts. Application of the adaptation measures is expected to lower the risk of hunger resulting from climate change.

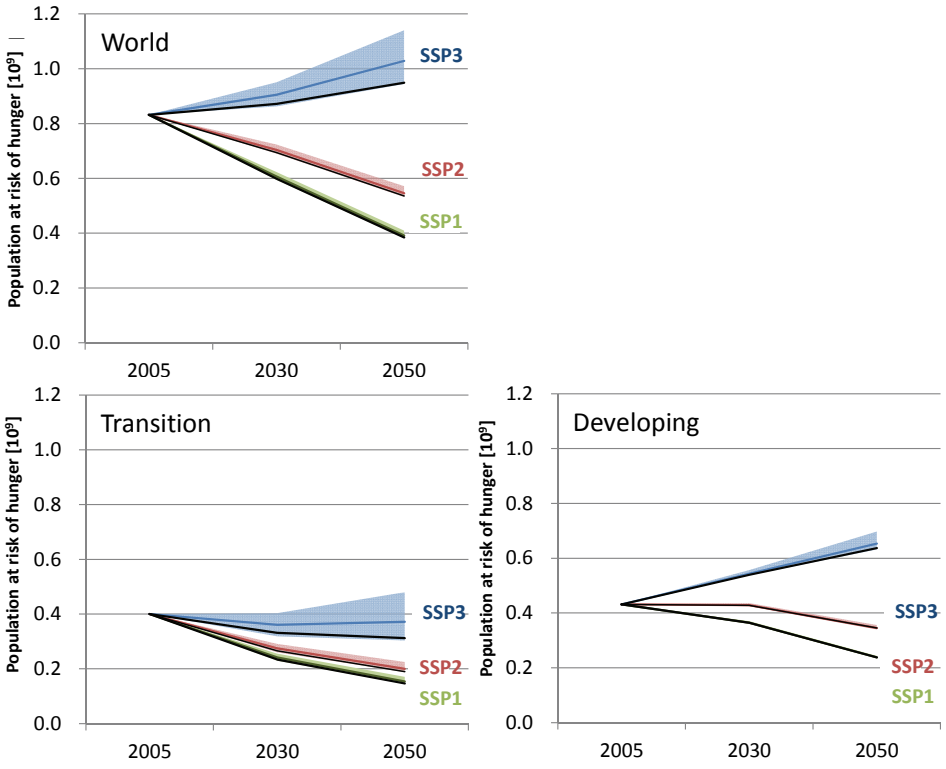


Fig. 4 Populations at risk of hunger under the three SSPs and four RCPs in the world, in transition, and in developing countries. Black lines show numbers of people at risk of hunger in the No Climate Change scenario; colored lines show median numbers at risk in the Climate Change scenarios; and shaded areas show the ranges of uncertainty under the four RCPs and the 12 GCMs.

4. Sustainable Social Systems Section

Staff of this section lead research projects related mainly to climate change. However, our intention is to deal not only with climate change per se, but also with other ecological and economic values, so that the outputs of our studies are directed toward a sustainable future for our society. What is a low-carbon society (LCS)? How can we achieve an LCS in the long term without harming our economy? What kind of adverse impacts of climate change are likely to occur without mitigation efforts? To what extent can we adapt to a new climate? How can we arrive at a multilateral agreement to alleviate these adverse effects? These are some of the research questions we address.

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

We used the AIM to assess energy and climate change scenarios after the Fukushima Nuclear Power Plant Accident, and the results were used as references in the discussions of the Global Environment Committee of the Central Council of Environment and the Energy and Environment Council of Japan. Our results showed that 5% to 17% GHG emission reduction can be achieved by 2020 compared with that in 1990, and 3% to 35% reduction can be obtained by 2030.

(2) Creation of LCS scenarios for Asian countries

We have used AIM in the past years to develop country-wise and city-wise LCS scenarios for China, India, Korea, Malaysia, Thailand, Indonesia, Vietnam,

Cambodia, Bangladesh, Jilin in China, Gyeonggi Province in South Korea, Ahmedabad and Bhopal in India, and Iskandar, Putrajaya, and Cyberjay in Malaysia. We have also organized stakeholder dialogues to determine how to make the LCS scenarios more suitable in Malaysia, Indonesia, Vietnam, and Cambodia. Moreover, in this fiscal year, we surveyed the use of a low-carbon education system in Japan and Iskandar, Malaysia, to enhance the stakeholder awareness of the feasibility of LCS strategies.

(3) Assessment of Electricity Saving Plan in the NIES

Since the earthquake on March 11, 2011, steady reduction in electricity consumption has become one of key actions to be taken in Japan as well as in the National Institute for Environmental Studies (NIES). In the FY2012, the NIES had no legally-bound target for reducing electricity consumption but held a voluntary target. The research consisted of two components: 1) Planning of electricity saving strategy in NIES based on historical data and 2) Monitoring of progress through continuous data collection.

Most of electricity consumption in the NIES is related to energy consuming research equipment such as C/T rooms (Constant Temperature-Humidity Rooms), freezers, refrigerators and super-computers. Therefore, electricity saving strategy in FY2012 included limiting operation time of these research facilities, changing C/T room setting, and minimizing operation of super computers during August and September. As the result, the Institute could reduce electricity consumption up to 82.7% at the minimum of the NIES target.

(4) Research into climate change impact and adaptation

We ran a project titled Comprehensive Research on Climate Change Impact Assessment and Adaptation Policies to assess the impact of climate change in Japan, and we used the results to create a simple integrated assessment tool, AIM/Adaptation[Policy]. In our assessment of the tool, we used four of the results from a global cycle model to examine the uncertainty of future climate change. Almost all of the indicators used to assess the impact of climate change were calculated at a fine spatial resolution that would be useful for promoting municipal adaptation policies. The tool was distributed to some municipalities and used for discussions of specific adaptation policies.

(5) International institutions beyond 2012

In this study, we looked for a plausible international agreement that could be achieved by 2015. The results of an online questionnaire survey conducted in January 2013 indicated that some countries prefer to agree on a Conference of the Parties (COP) decision and political declaration rather than a new protocol, although the Durban Platform (a COP17 decision made in 2011 to start negotiations with the aim of achieving agreement by 2015) calls for “a protocol,

another legal instrument or an agreed outcome with legal force under the UNFCCC [United Nations Convention on Climate Change]" that would be "applicable to all Parties." The results also indicated that both Annex I and non-Annex I parties prefer a "legally binding emission target" over a "voluntary emission target;" "legally binding mitigation actions" over "voluntary actions;" and a "financial mechanism that involves a variety of financial resources including private investments" over a "financial mechanism that deals only with public funding." Thus Annex I and non-Annex I countries do not have conflicting positions regarding the fundamental architecture of the new agreement.
We also conducted a study to investigate financial instruments that could be implemented within the Asian region to enable it to achieve an LCS. The results showed that any financial mechanism would require all countries in Asia to play roles appropriate to their capacities, and that investment by private firms would be important in achieving an LCS.

5. Eco-City System Research Section

This section pursues studies related to environmentally and economically sustainable cities, focusing on local energy systems, regional resource circulation, transportation systems, and land-use-control management 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 found 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.

Our study of the Tokyo Metropolitan Region (TMR), for example, is seeking the determinants of resource recycling boundaries by using a case study approach. Our case study is examining the recycling of waste plastics as inputs to cement and iron plants in the TMR, and the findings are generalized to other types of recyclable municipal solid waste. In the case study, we determine the number, capacities, and locations of regional recycling centers (RRCs) that would enable

waste plastics pre-treatment services (separating, compressing, and bailing) to be provided to the whole region at minimum cost. Rather than minimizing the cost for one single facility, it is important that all municipalities within the study region be able to receive services with a total minimum cost so that the fiscal burden of the public sector can be alleviated and the overall recycling efficiency can be improved. Municipal Recycling Centers (MRCs) are required by the Recycling Law on Container and Packaging and are found in most Japanese large cities; their existence provides a realistic foundation for the case study to assume that RRCs can be hosted by large cities. RRCs are designed to meet regional demands for recycled materials and can replace the smaller-scale MRCs for such functions as separation, compression, and bailing of waste plastics. Figure 5 shows the optimum localization of RRCs in the TMR.

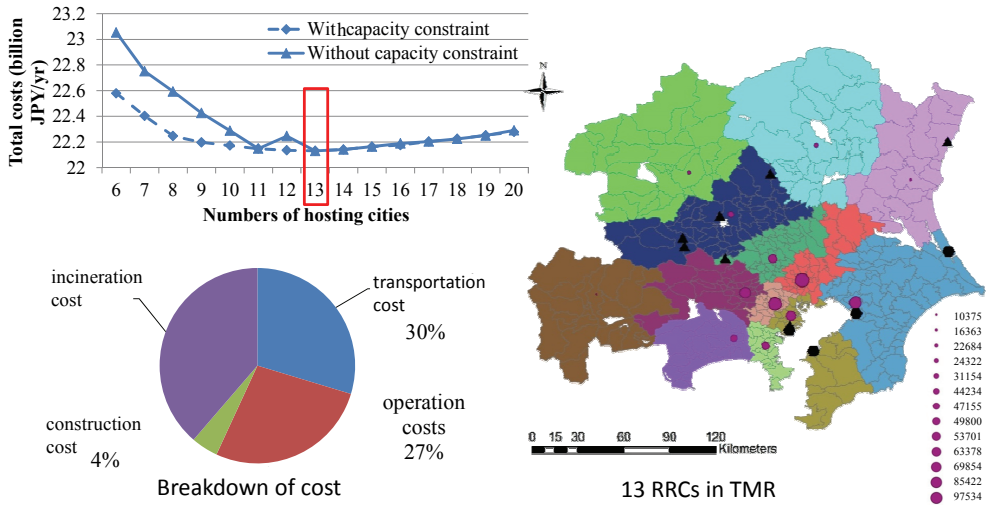


Fig. 5 Example model outputs: results of the standard scenario in 2025 (cost and scale)

Over 1/3 cheaper than new pre-treatment facilities built in each municipality

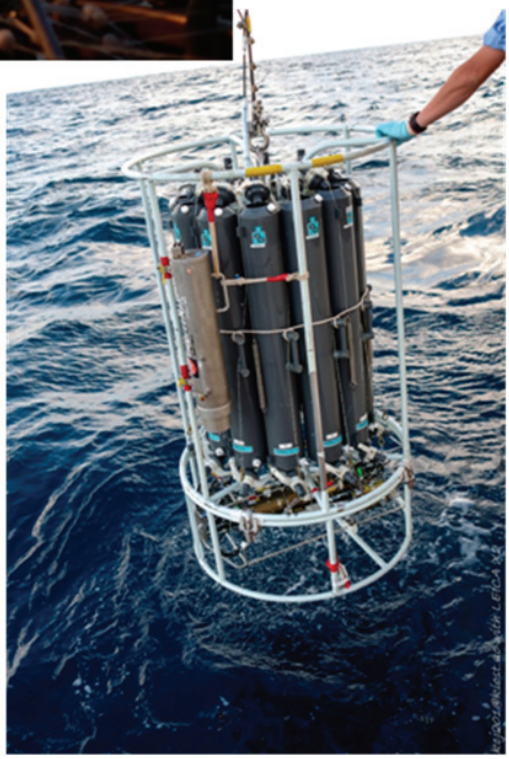
(2) Study of long-term CO_2-reduction strategies implemented by the transport sector toward an LCS

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 NIES's Environmental GIS Website (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)



a) Japan Sea viewed from a research vessel
b) Conductivity-temperature-depth profiler with Rosette multi-bottle samplers (CTD/RMS)

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

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

Following are brief accounts of some of the important results of our research in FY 2012.

Development of a highly sensitive method for analysis of polycyclic aromatic hydrocarbons and their derivatives

We are developing new methods for global and selective detection of environmental pollutants. In this project, we have developed a highly sensitive method of analyzing polycyclic aromatic hydrocarbons (PAHs) and their derivatives (oxygenated, nitrated, and methylated PAHs) in trace particulate samples by using thermal desorption followed by comprehensive two-dimensional gas chromatography coupled with tandem mass spectrometry (TD-GC×GC-MS/MS) with a selected reaction-monitoring mode. The instrumental detection limits were 0.03 to 0.3 pg (PAHs), 0.04 to 0.2 pg (oxygenated PAHs), 0.03 to 0.1 pg (nitrated PAHs), and 0.01 to 0.08 pg (methylated PAHs). The sensitivity of this method was one or two orders of magnitude greater than that of TD-GC-HR (high-resolution) MS or TD-GC×GC–Q (quadrupole) MS. For small amounts (10 to 20 μg) of standard

reference materials provided by the U.S. National Institute of Standards and Technology (NIST, SRMs 1649a and 1650b, urban dust and diesel exhaust particles, respectively), the results of TD-GC×GC-MS/MS agreed with the certified or reference values within a factor of two. We applied this method to size-resolved diesel exhaust particles from an 8-L diesel engine with no exhaust after-treatment system. The engine was operated under a no-load condition (2000 rpm, 0 Nm) or under a JE 05 transient test condition. Figure 1 shows the concentrations of PAHs and PAH derivatives in nanoparticles (18 to 32 nm) and accumulation-mode particles (100 to 180 nm) in diesel exhaust, as measured under the JE05 transient and no-load conditions. The PAH profiles differed between the driving conditions, but they did not differ markedly between particle sizes. Volatile PAHs and PAH derivatives (retention time <18 min), such as fluoranthene and pyrene, which are present in diesel fuel, were dominant in JE05 mode, whereas less volatile PAHs, oxy-PAHs, and methyl-PAHs (retention time >20 min) were dominant under no-load conditions. This is probably due to the difference in the relative contributions of fuel and oil: fuel makes a large contribution to the particulate composition in JE05 mode, whereas oil largely contributes to particulate composition under no-load conditions. The finding that nitro-PAH concentrations were higher under transient conditions than under no-load conditions is reasonable, because nitro-PAHs can be formed from a reaction between nitrous gases and PAHs, and the average NOx concentration in JE05 mode was 1.5 times that under no-load conditions.

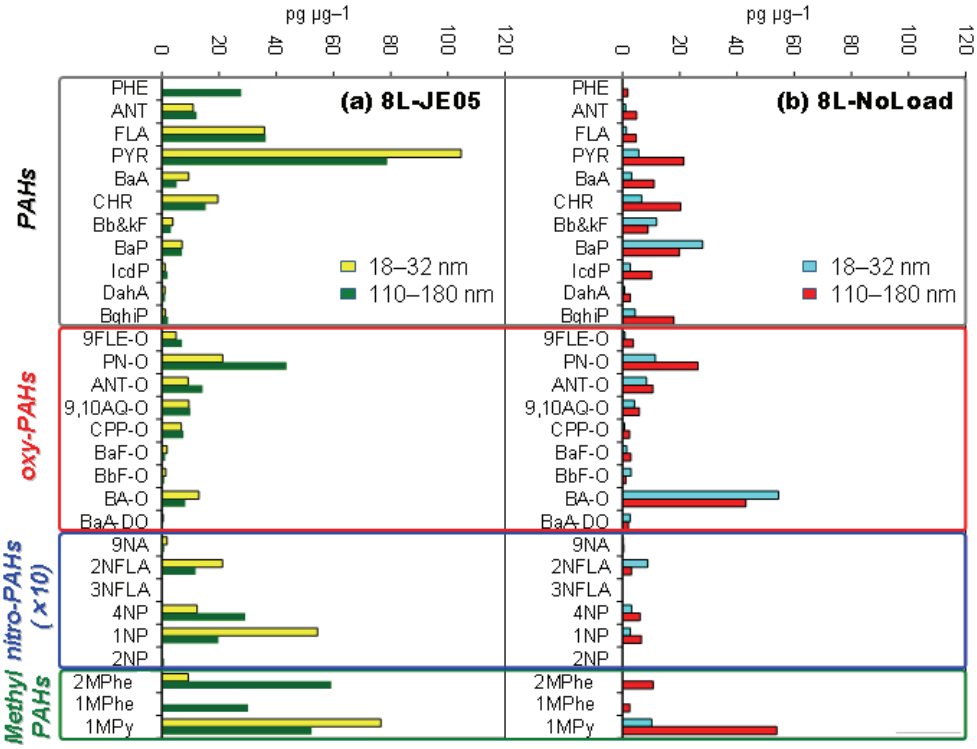


Fig. 1 Concentrations of PAHs and PAH derivatives in nanoparticles and accumulation-mode particles in diesel exhaust. (a) 8-L diesel engine, JE05 test condition. (b) 8-L diesel engine, no-load condition. *n* = 1 for each sample.

Characteristics of anthropogenic radionuclides derived from Fukushima and observed in the atmosphere at Tsukuba

During the serious accident at the Fukushima Daiichi Nuclear Power Plant, a huge quantity of radionuclides was released into the atmosphere and ocean. We measured anthropogenic radionuclides in surface air at Tsukuba, about 170 km from the power plant. On 15 March 2011, we detected the radioactivity released from the Fukushima accident in air samples at Tsukuba. The major radionuclides that we observed were radioiodine (^{131}I, ^{132}I, ^{133}I) and radiocesium (^{134}Cs, ^{136}Cs, ^{137}Cs). Radioiodine consisted of gaseous and particulate forms; as an example, the temporal variation in particulate ^{131}I activity as a percentage of total ^{131}I activity in surface air is shown in Figure 2. Particulate ^{131}I activity ranged from 0% to 86% and increased upon arrival of the plumes from major emissions from the power plant. This suggests that particulate ^{131}I was preferentially emitted into the atmosphere compared with the gaseous form at times when the emission rate was large. After radionuclide activity peaked on 15 March 2011, the concentration of power-plant-derived radionuclides in the surface air decreased rapidly. The activity median aerodynamic diameter of ^{131}I-bearing particles was 0.7 μm, whereas those of ^{134}Cs- and ^{137}Cs-bearing particles were larger than 1 μm. The ^{134}Cs/^{137}Cs activity ratio in surface air at Tsukuba was 1.1±0.1 and did not vary over time. The ^{136}Cs/^{137}Cs activity ratio was different: the initial ^{136}Cs/^{137}Cs ratio during the major emission (15 to 22 March) was 0.21, whereas that following a minor emission (29 March to 9 April) was 0.13.

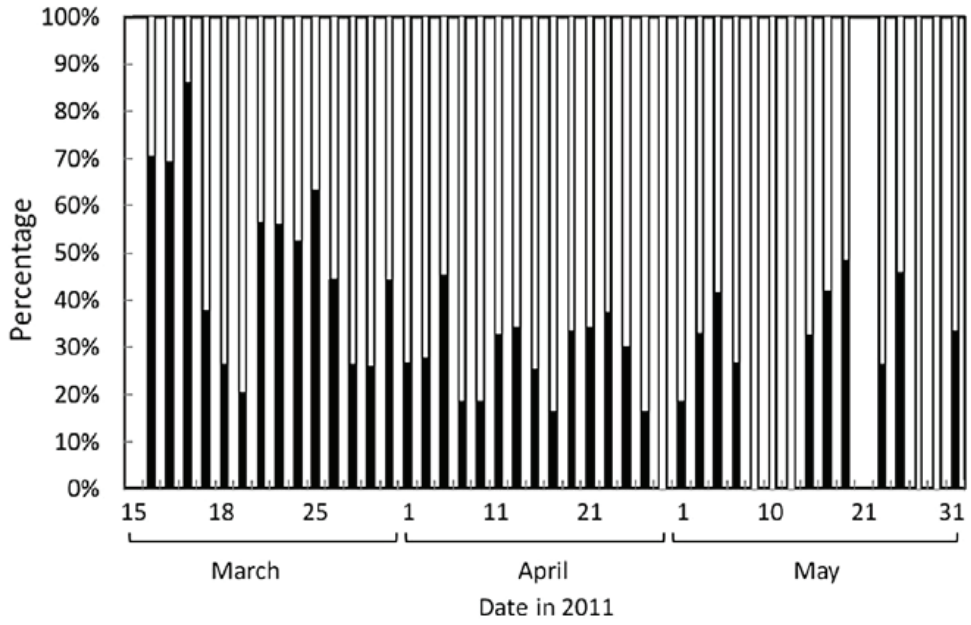


Fig. 2 Percentages of particulate ^{131}I (solid bars) and gaseous ^{131}I (open bars) relative to the total ^{131}I observed at Tsukuba during March–May 2011.

Spatial distribution of radiocarbon in the southwestern Japan Sea immediately after bottom-water renewal

The Japan Sea is an almost landlocked marginal sea in the northwest Pacific Ocean. In April 2001, immediately after bottom-water renewal in the Sea of Japan, we performed a hydrographic survey in the southwestern part of this sea, south of the area of bottom-water formation, and obtained vertical profiles of radiocarbon (^{14}C) from seven stations along a line at 130.5°E from the Tsushima Basin to the southernmost Japan Basin. Figure 3 shows the north–south sections of $\Delta^{14}C$ (i.e. the ‰ deviation in the $^{14}C/^{12}C$ ratio of samples from those of a standard defined as the $^{14}C/^{12}C$ ratio of atmospheric CO_2 in 1950), dissolved oxygen, and potential temperature along the 130.5°E line. The vertical profile at the southernmost Japan Basin station (G18) was unique. At a depth interval from 800 to 2000 m, the $\Delta^{14}C$ values were clearly higher at station G18 than at the other stations, the maximum difference of $\Delta^{14}C$ being more than 50‰. Although the potential temperature varied little within the observation area, dissolved oxygen was slightly higher on isobaths below 500 m at station G18 than at the other stations. These results suggest that bottom water newly renewed in late January to early February 2001 had flowed southward to the southernmost Japan Basin station within just 2 months. There was no evidence that the water had been transported into the Tsushima Basin during the same time period.

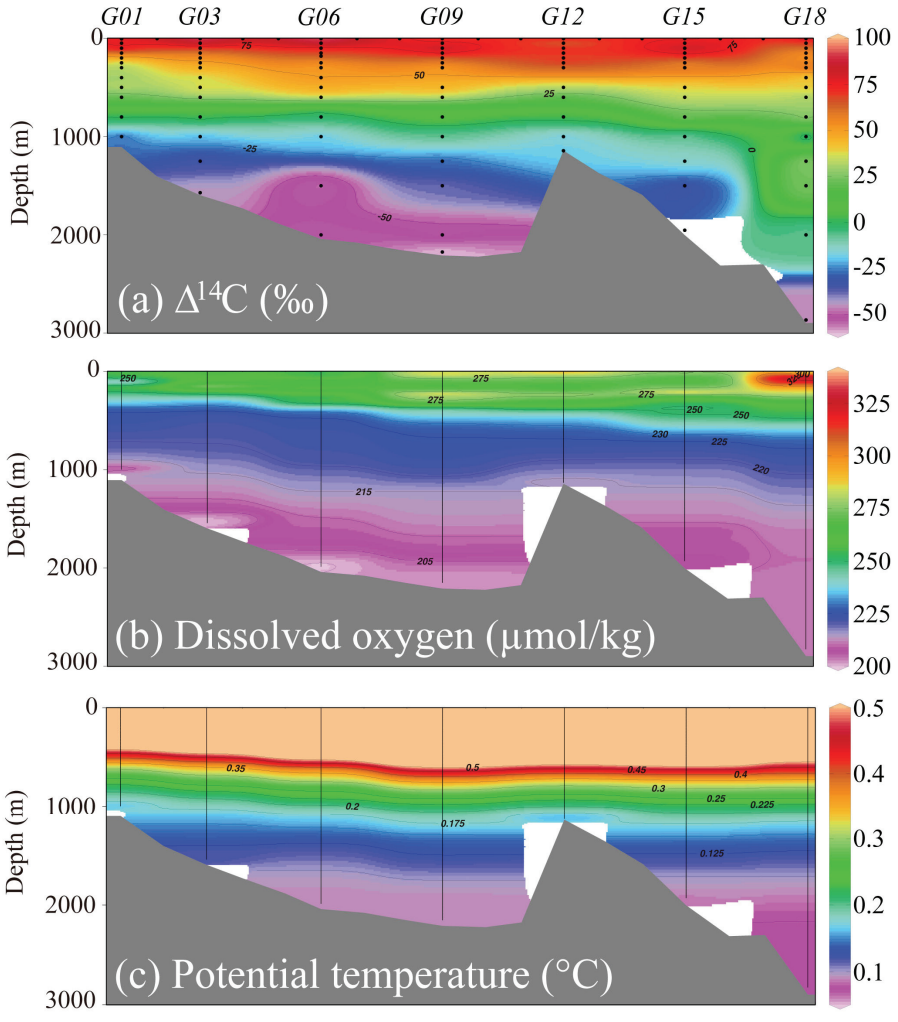


Fig. 3 North–south sections, along a line at 130.5°E, of $\Delta^{14}C$, dissolved oxygen, and potential temperature. Dots in (a) indicate sampling depths.

Transformation of diphenylarsinic acid and related compounds in groundwater: Production of thiol-containing arsenicals

During routine analyses of groundwater samples contaminated with diphenylarsinic acid (DPAA) at Kamisu, Ibaraki, Japan, we obtained data indicating that unknown arsenic compounds accounted for up to 75% of the total arsenic in some of the samples. An analysis using liquid chromatography in combination with elemental mass spectrometry and tandem molecular mass spectrometry indicated the presence of two arsenic-containing unknowns with molecular masses of 294 and 232, which appeared to slowly be converted into DPAA and methylphenylarsinic acid (MPAA), respectively. For example, when a sample was allowed to naturally oxidize and was then reanalyzed by liquid chromatography–inductively coupled plasma-mass spectrometry, the unknown peaks disappeared, with a large increase in the size of the peaks for DPAA and MPAA/phenylarsonic acid (PAA). These observations suggested the presence of thio-arsenicals in which the oxygen atom on arsenic had been substituted with a sulfur atom—that is, phenylmethyldithioarsinic acid (PMdtAA) and diphenyldithioarsinic acid (DPdtAA). These assignments were confirmed by comparison with chemically synthesized compounds using liquid chromatography combined with high-resolution time-of-flight mass spectrometry. Possible schemes for the biosynthesis of DPdtAA and PMdtAA from DPAA and PAA in the environment are shown in Figure 4.

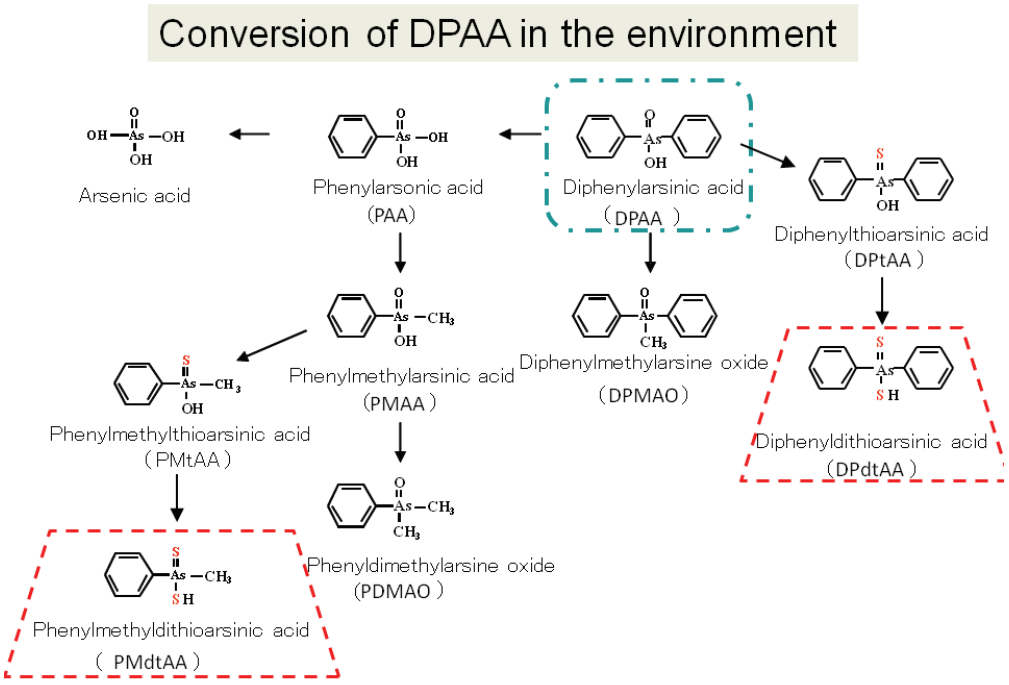


Fig. 4 Biosynthesis schemes for the conversion of DPAA and PAA into DPdtAA and PMdtAA in the environment.

Fluorescence from atmospheric aerosols observed with a multi-channel lidar spectrometer

We constructed a lidar for measuring fluorescence from atmospheric aerosols by using a third harmonic Nd:YAG laser, a 1-m diameter telescope, and a 32-channel time-resolved photon-counting spectrometer system. The spectra of the backscattered light were recorded in a wavelength range from 345 to 525 nm, with 5.8-nm resolution over a height range up to 15 000 m, with 15-m height resolution. The lidar spectrometer signals were accumulated for 10 min and recorded. The fluorescence spectra and vertical distributions of fluorescent aerosols in the lower atmosphere were observed at night with an excitation wavelength of 355 nm. Figure 5 gives examples of fluorescence spectra for different aerosol cases and for cloud. As clearly seen in the figure, the fluorescence spectra were observed in a wavelength region longer than the Raman scattering channels of O_2, N_2, and H_2O. The broad fluorescence intensity was defined by integrating the signals observed between 420 and 520 nm. The intensity of the nitrogen Raman scattering channel was used to normalize the signal intensity of the spectral channel at each height. Figure 6a is an example of the time–height indications of broad fluorescence. Comparison with the time–height indications of the non-spherical aerosol (dust) extinction coefficient (Figure 6b) and the spherical (mostly air pollution) aerosol extinction coefficient (Figure 6c) derived from the Asian Dust lidar network data revealed that the fluorescence distribution pattern was similar to that of Asian dust and the signal intensity was high. Figure 7 is another example of fluorescent aerosol distribution. In this case, the dust extinction coefficient (Figure 7b) is low, and the distribution pattern of the fluorescence (Figure 7a) is similar to that of the spherical aerosol extinction coefficient (Figure 7c). A rough estimation of the fluorescence efficiencies from these aerosols revealed that they were comparable to that of nitrogen Raman scattering; this suggests that it may be possible to make a compact Raman-Mie-fluorescence lidar for aerosol monitoring.

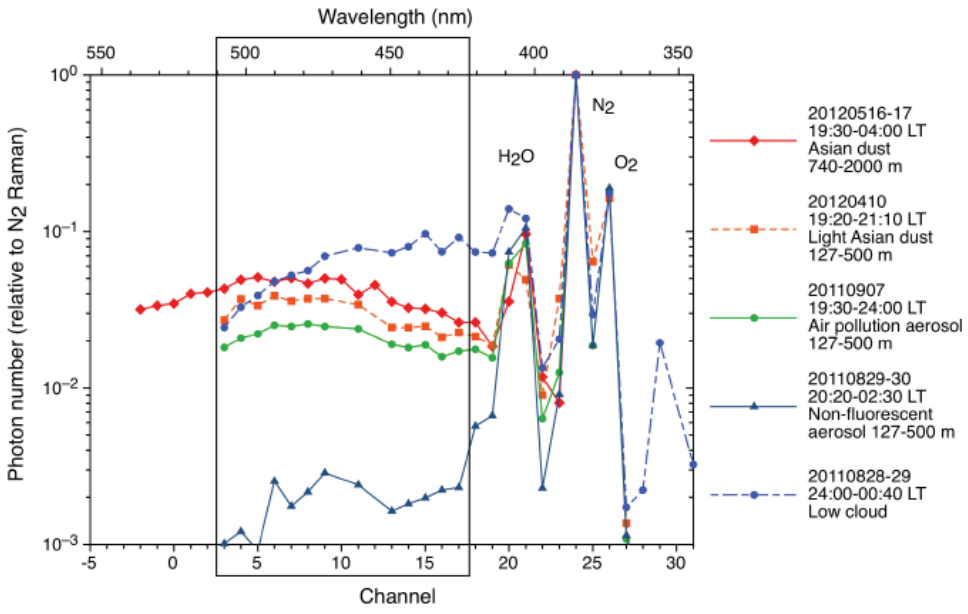


Fig. 5 Examples of fluorescence spectra of aerosols and cloud. The detector sensitivity was corrected by normalizing the intensity of N_2 Raman scattering channel. The rectangular area defines the broadband fluorescence used to calculate integrated intensity.

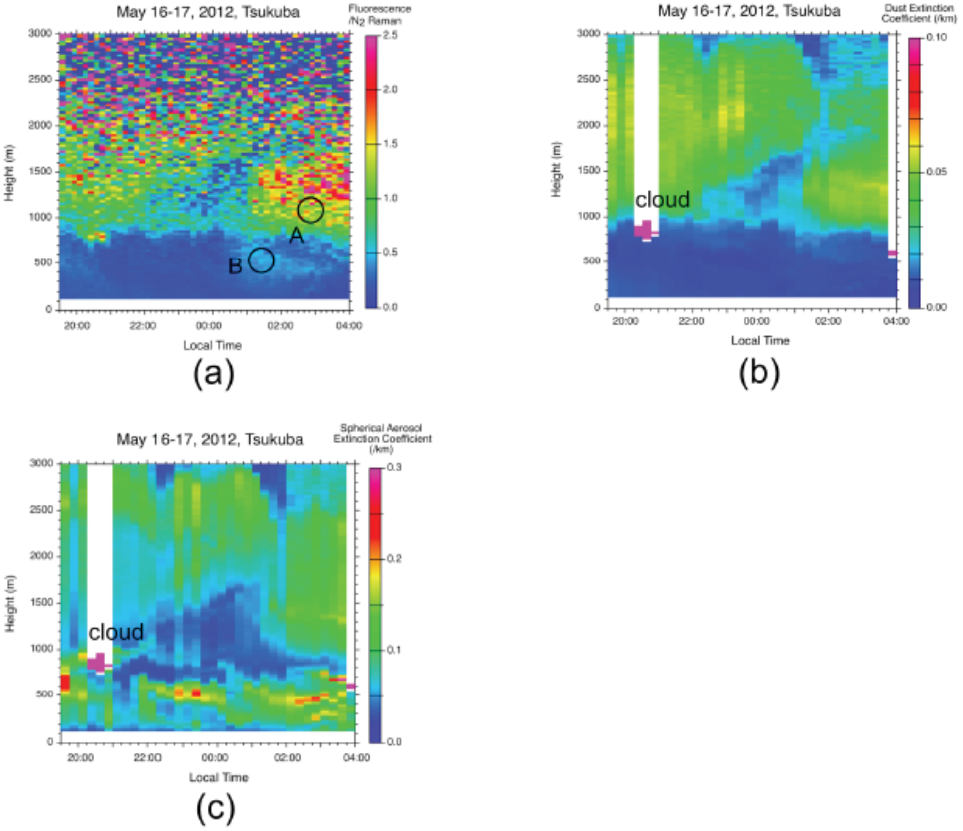


Fig. 6 Time–height indications of (a) broad fluorescence, (b) the non-spherical aerosol extinction coefficient at a wavelength of 532 nm, and (c) the spherical aerosol extinction coefficient at 532 nm, in the case of Asian dust from 16 to 17 May 2012. Clouds are indicated in magenta, and areas for which no data are available (e.g. above the clouds) are indicated in white.

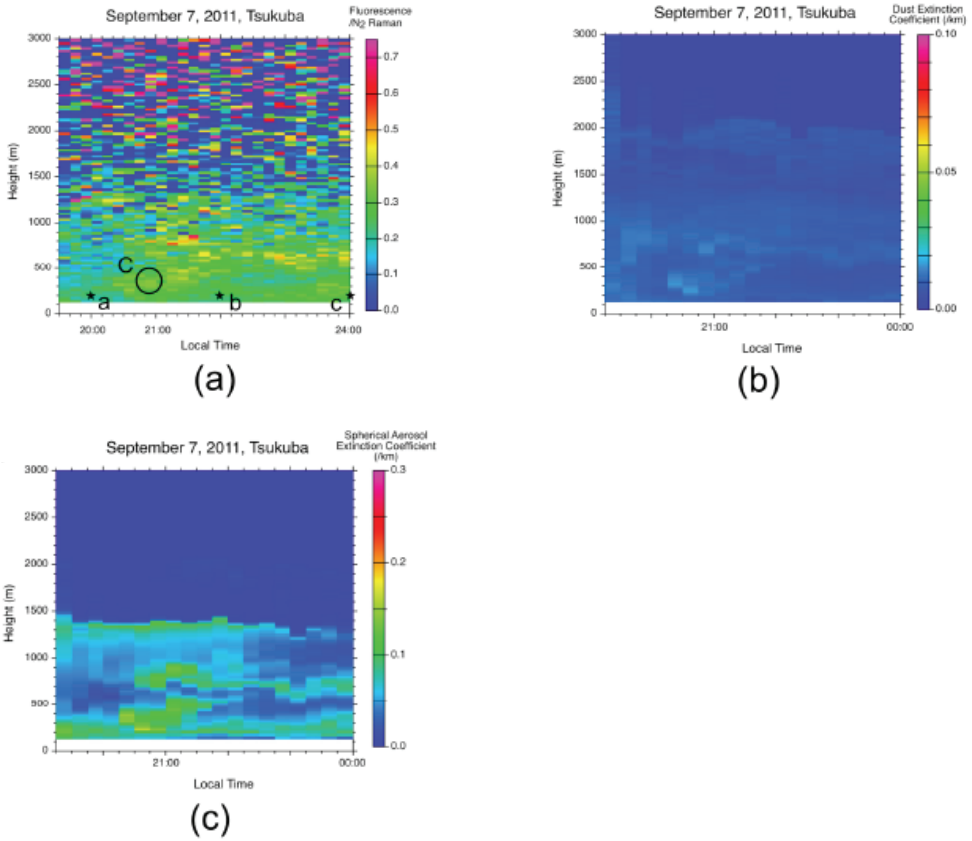


Fig. 7 The same as in Figure 6, but for air-pollution aerosol on 7 September 2011.

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 2013. Registered users outside NIES can use the supercomputer system through the Tsukuba wide-area network via the SINET (Science Information Network) connection to the Internet.

Fig. 1
Supercomputer
(NEC SX-8R/128M16)

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 2012, 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 2013, the NIES library held 60 434 books, 327 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.

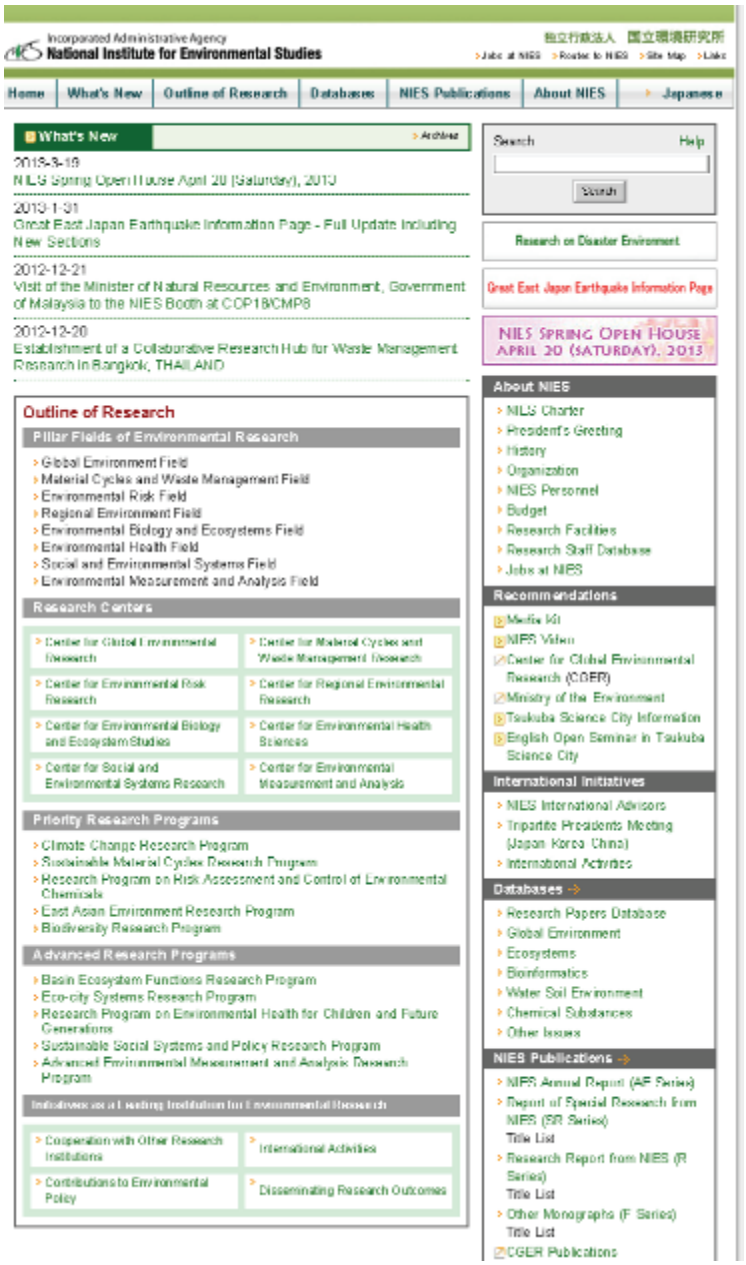
Fig. 2 Library

2. NIES public relations activities

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

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.



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.

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

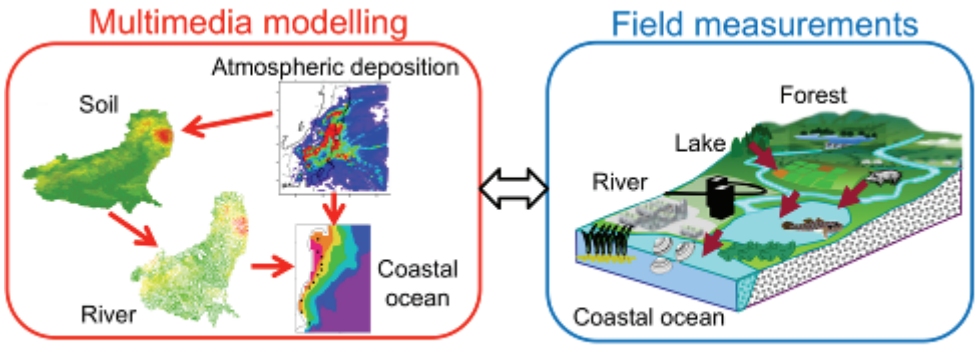
The Department, with the cooperation of MOE, has been using GIS to develop an environmental data provision system. This system helps users to easily understand the status of the environment by showing data on environmental quality and other information on maps. The system has been publicly available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

b. Tasks commissioned by the Ministry of the Environment

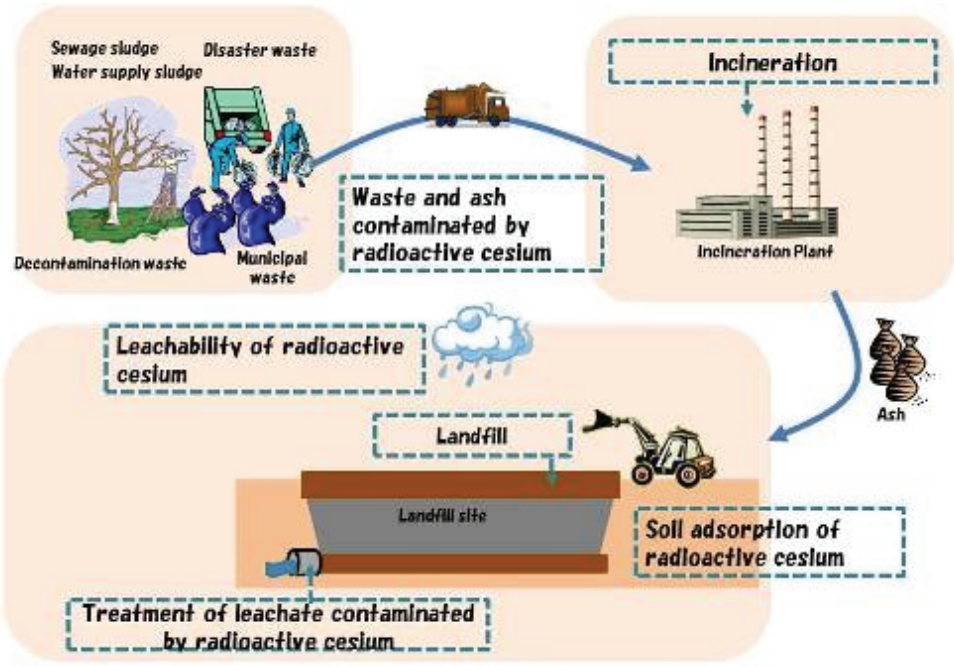
In FY 2012 the Department performed the following two tasks commissioned by the Ministry of the Environment:

- maintenance and support of a data entry system for living environment data, including data on noise, vibration, and offensive odors.
- conversion of hourly values of regular air monitoring data to standard format.

Radioactive Materials and Environmental Disaster Research



Schematic diagram of multimedia environmental research



Proper treatment of waste contaminated by radioactive materials

1. Establishment of technologies and systems for managing disaster wastes 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 Nuclear Power Plant accident left the terrible problem of solid waste contaminated by radioactive substances. We are performing various types of urgent research on behalf of central and local governments into the appropriate management of these wastes 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) Clarification of fundamental properties and behavior mechanisms of radioactive substances

1) Equilibrium calculation of cesium behavior during waste incineration

We improved the thermodynamic property database in our thermodynamic equilibrium software in terms of cesium (Cs) chemicals, and we then calculated the equilibrium composition of Cs chemicals during the incineration of municipal solid waste (MSW) and waste biomass. Figure 1 is an example of the results of combustion at 850 °C. Incineration resulted in the formation of CsCl gas, which is highly water soluble, and $CsAlSi_2O_6$ solid, which is highly water insoluble. These solubility characteristics successfully explained the leaching behavior of radioactive Cs from MSW incineration ash. Figure 1 also shows that the composition of the waste strongly affected the percentages of gaseous and solid Cs chemicals formed.

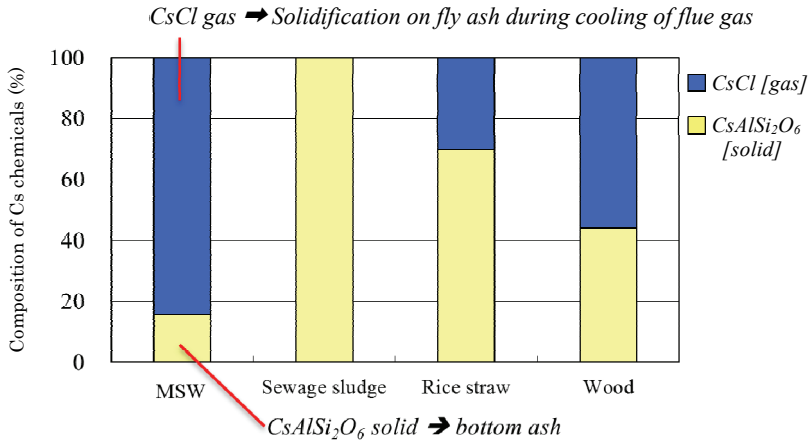


Fig. 1 Equilibrium composition of Cs chemicals during waste combustion at 850 °C

2) Leaching characteristics of radioactive Cs from soils and plants

Information on the leaching characteristics of radioactive Cs is essential in the long-term storage of soil and plants. In this research, we tested six types of plant sample and three types of soil sample to evaluate Cs leaching behavior. For extraction, we used pure water followed by ammonium acetate. Figure 2 illustrates the leaching percentages of ^{137}Cs (i.e. the amounts of ^{137}Cs leached as percentages of the total amounts of ^{137}Cs). The water-soluble fraction was very small in all samples (either below the quantification limit or less than 1%). The ion exchangeable fraction (i.e. the fraction extractable in 1 N-ammonium acetate) ranged from 0.3% to 2.6% in the plant samples and 1.4% to 6.0% in the soil samples. These results imply that more than 90% of the ^{137}Cs in plants and soil is present in other, more insoluble, chemical forms than these water-soluble or ion-exchangeable fractions.

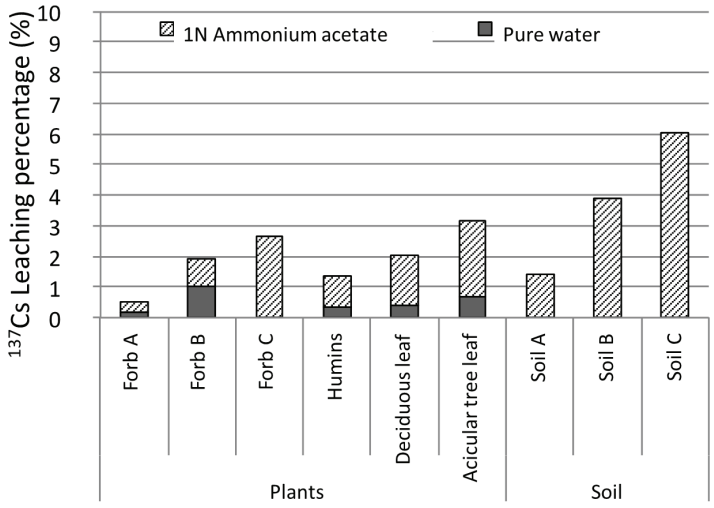


Fig. 2 Leaching percentages of ^{137}Cs from plants and soils, as assessed by extraction with ammonium acetate and pure water.

3) Landfill soil adsorption ability

The leachate at landfill sites where incineration fly ash was being disposed of had high salinity and high electrical conductivity (EC), and the potassium ion concentration was also high—10 times that of seawater. The ability of a soil sorption layer installed at such landfill sites to adsorb radioactive Cs would therefore be low. According to reports from observations at Fukushima and Chernobyl, the mobility of radioactive Cs in the ground surface remains less than several centimeters, but that in landfill sites differs. The distribution coefficient of radioactive Cs, as determined by batch-type adsorption testing using the leachate from fly ash as a solvent, is about 1/10 to 1/100. The distribution coefficient of ^{137}Cs is in inverse proportion to the EC of the leachate from fly ash: for instance, the distribution coefficient decreases 0.1 times if the EC increases 10 times (Fig. 3). From the results of desorption tests, we found that the rate of desorption from the soil sorption layer increases if seawater or ammonium acetate is used as a

solvent, as compared with using water. In addition, if leachate from uncontaminated fly ash is used as a solvent, then the desorption rate is often greater than that using ammonium acetate.

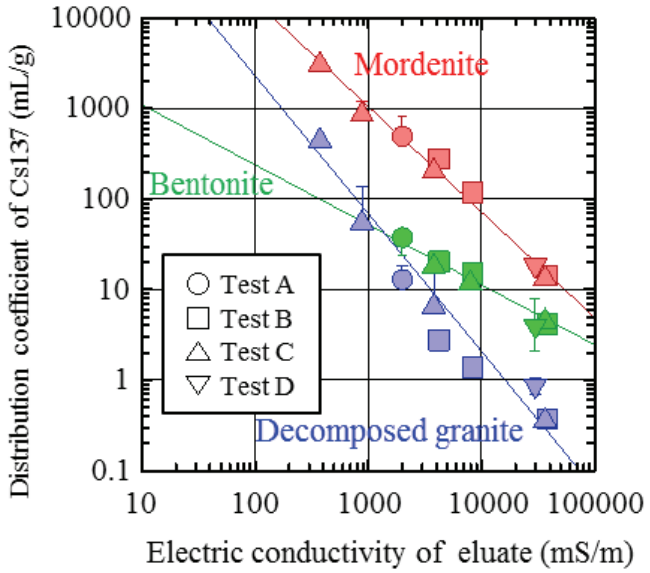


Fig. 3 Influence of electrical conductivity of fly ash leachate on the distribution coefficient of ^{137}Cs.

(2) Development, optimization, and assessment of treatment, disposal, and recycling technologies

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

We measured radioactive Cs and other elements in flue gases and solid samples from a stoker furnace with an ash-melting system and from a gasification/melting furnace. We found that (1) the amount of Si present affects the fate of radioactive Cs in the bottom ash and slag, and the amount of Cl present affects that in the fly ash from both incineration and melting processes, and (2) the ratio of CaO to SiO_2 may be a practical index of the radioactive Cs content of the slag that is produced.

We also examined the behavior of Cs in the gasification process by using a bench-scale apparatus. The results showed that temperature and atmospheric conditions affect the fate of Cs and the leachability of Cs from solid residues.

To concentrate Cs into the final residue, we conducted a large-scale experiment (3 t/day) in a surface-melt furnace. Model soil and leaf mold mixtures containing ^{133}Cs were fed into the furnace under various conditions. The rate of Cs evaporation from the feeding material increased when the operating temperature and the proportions of leaf mold and $CaCl_2$ added increased.

We also quantified radioactive Cs accumulation in refractory brick samples from

incineration plants. We found that one of the main factors influencing the accumulation of radioactive Cs was the duration of exposure of the refractory brick to flue gas containing radioactive Cs. The fate of radioactive Cs in combustion furnaces was also investigated by using a mathematical simulation and experimental model of adsorption onto the surface of, and penetration into, the refractory brick. A small-scale thermal experiment using model refractory samples and a heated tubular reactor was conducted to obtain parameters on the entry of radioactive Cs into the matrix of the refractory brick and its accumulation there. The result showed that the porosity of the refractory brick influenced the amount of radioactive Cs adsorbed.

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

As of 31 March 2013, a total of 80,000 t of ash contaminated with $^{134/137}$Cs at an activity concentration of more than 8000 Bq/kg had been produced by municipal solid waste incineration in Japan. The ash has been stored on site, but a shortage of storage areas has now become an urgent issue.

The results of leaching tests of fly ash collected from 10 incineration facilities revealed that the Cs contained in fly ash was easily leachable with water at ambient temperature. The leaching percentage ranged from 43% to 95% (average, 75%). An average of 90% of radioactive Cs was removed from the fly ash in a bench test of washing followed by Cs adsorption (Fig. 4). This meant that the $^{134/137}$Cs activity concentration in dehydrated washed fly ash would be less than 8000 Bq/kg if contaminated fly ash containing a $^{134/137}$Cs activity concentration of up to 80,000 Bq/kg was applied. Radioactive Cs in the leachate was removed with zeolite or Prussian blue and safely stored at very small volume. The activity concentration of $^{134/137}$Cs in the adsorbents reached 10 MBq/kg, whereas the activity concentration of $^{134/137}$Cs in the effluent was less than 10 Bq/L.

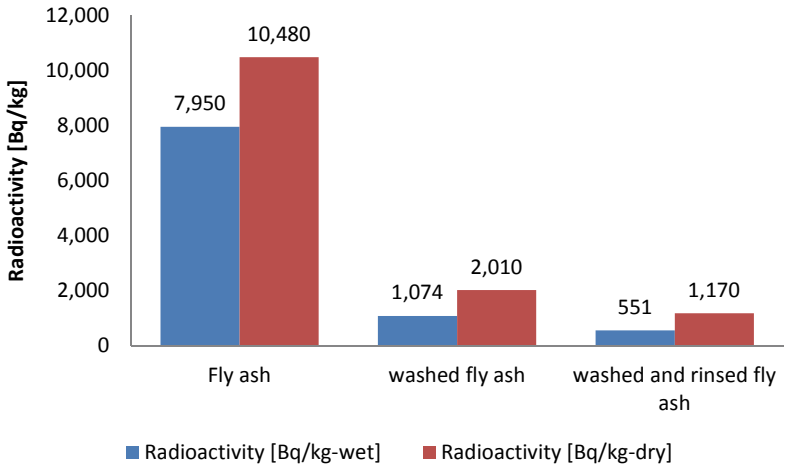


Fig. 4 Radioactive cesium removal from fly ash by washing and rinsing with water

3) Application of concrete technologies

MOE is proposing the use of reinforced concrete pit structures composed of 12 pits of 10 m width, 5 m depth, and 5 m height as a units for the final disposal of designated wastes contaminated by radionuclides (Fig. 5). One type of designated waste is fly ash from municipal solid waste incineration (MSWI). Besides containing water-soluble Cs salts, this MSWI product is characterized by large amounts of $CaCl_2$ and alkali chlorides present in the order of several tens of mass %. $CaCl_2$ is deliquescent and can form a liquid phase that can be harmful to steel-reinforced concrete if the impermeable coating on the concrete is accidentally broken: concentrated chloride solution accelerates steel corrosion and alkali silica reaction (ASR)-related expansion of the concrete. To enhance safety in the event of accidents, we are considering ways of preventing, for a period of time on the order of 100 years, the cracking of thick concrete by thermal stress from cement hydration, by drying shrinkage, by ASR, and by steel corrosion after Cl penetration. In an effort to find a solution, we are testing fly ash from coal-fired power plants and simulating Cl and Cs transport from fly ash of MSWI.

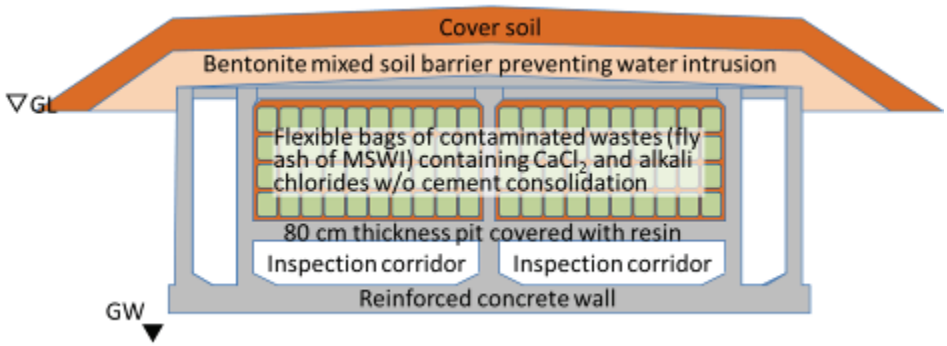


Fig. 5 Concrete pit as a final disposal site proposed by MOE.

4) Landfill and storage technology for contaminated wastes and soil

We have been examining leachability from contaminated wastes or soil in association with the use of impermeable cappings and impermeable lining systems. These two components are commonly placed in landfill sites that store incineration ash contaminated with radioactive Cs, and temporary sites for storing contaminated wastes and soils. In the case of temporary storage sites for decomposable decontamination wastes, gas-permeable and water-impermeable sheets are used for capping. Clayey capping systems are installed at landfill sites to combat differential settlement. To assess the impermeability of these capping systems, we constructed a demonstration site and have started a monitoring of water balance. Moreover, from a series of experiments, we found that landfilling of fly ash led to high salinity and elution of all of the radioactive Cs through contact with the pore-water; the soil sorption layers under the landfill test site did not have enough sorptive capacity. We used this knowledge to numerically calculate the fate of radioactive Cs in landfills, and we found that the peak

leachate concentration would occur as many as several decades or hundreds of years after landfilling (Fig. 6).

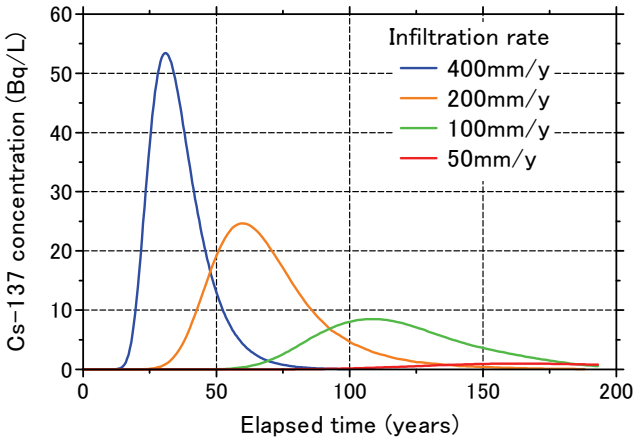


Fig. 6 Projected long-term behavior of radioactive Cs at a landfill site.

(3) Establishment of monitoring technologies for radioactivity and application to waste management

We conducted a field survey to investigate the radioactive Cs contamination status of fiber-reinforced-plastic (FRP) boats that were damaged by the Great East Japan Earthquake and resulting tsunami and were then contaminated by nuclear fallout from the accident at the Fukushima No. 1 nuclear power plant. Radiation dose rate was measured in selected boats and in the surrounding environment by using radiation survey meters (i.e. a thallium-activated sodium iodide [NaI(Tl)] scintillation counter and a Geiger-Müller counter) and a radiation-sensing camera to visualize the dose rate distribution within the area. In addition, FRP parts, sediment deposits, and stagnant water inside the boats were sampled and their ^{134}Cs and ^{137}Cs radioactivity were measured by gamma-ray spectrometry using NaI(Tl) scintillation or a germanium detector. The monitoring results revealed that the presence of materials or sediments in the boats enhanced the radiation levels, but that these levels could be substantially reduced by decontamination operations such as removal and washout of the materials or sediments (i.e. by implementing countermeasures for surface-deposited radioactivity; Fig. 7). Consequently, the survey and decontamination approaches were considered a good model and promoted prompt dismantlement, removal, and further disposal or recycling by the relevant local authorities.

Fig. 7 Decontamination (removal and washout of materials or sediments) of boat wastes in Soma, Fukushima.

(4) Elucidating radioactive Cs flows in anthroposphere to optimize management systems of Cs-contaminated waste

We estimated the radioactive Cs concentrations of MSW by using data on MSW incineration ash and then analyzed their regional and temporal trends. There was seasonal variation (the concentration increased in early summer and decreased in winter, Fig. 8), but the overall trend was for the concentration to decline at a faster rate than the physical half-life of radioactive Cs. We also revealed that the level of radioactive Cs in MSWI ash was related to the contamination level (air dose rate) of the area and the type of incineration plant. We have conducted a similar analysis of sewage sludge.

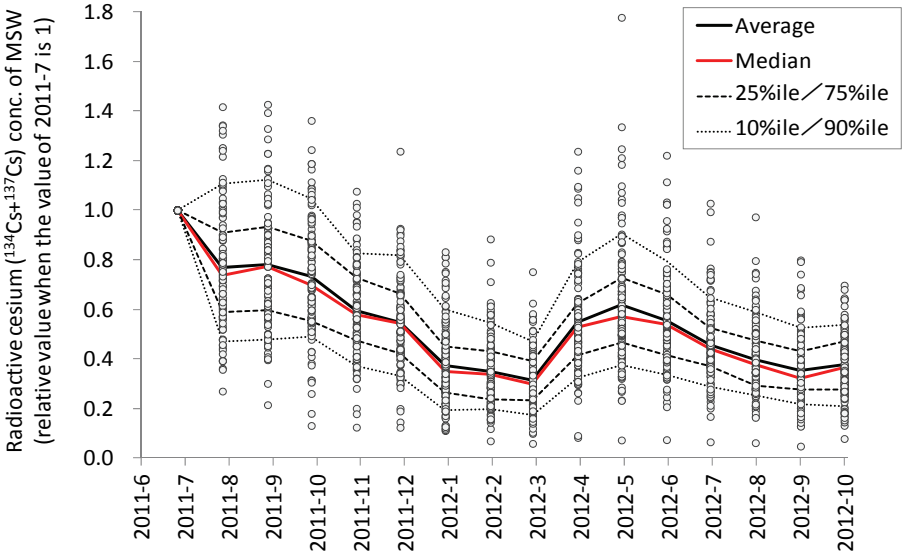


Fig. 8 Temporal trends in radioactive Cs concentrations in municipal solid waste in eastern Japan.

(5) Disaster waste management methods

For quick and sound disaster waste management (DWM), in addition to technical aspects, institutional and managerial aspects play important roles. Drawing from

theories of policy implementation and public management, we set up an analytical framework (Fig. 9) and analyzed the impact of DWM-related circulars and orders released after the Great East Japan earthquake on the effectiveness of DWM within the context of this disaster. Our analysis of these documents, together with an analysis of administrative behaviors in the devastated municipality and their effectiveness, suggested that although loosening legal requirements by having institutions make special post-disaster arrangements facilitates quick DWM, institutional arrangements that pose additional administrative burdens could potentially lead to environmental, health and safety risks.

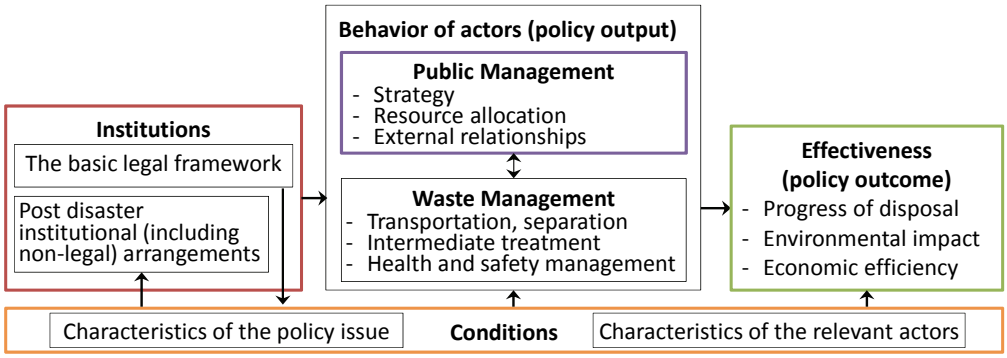


Fig. 9 Policy implementation process within the context of disaster waste management

2. Study of dynamics of radioactive materials in multimedia environments

A nuclear accident at the Fukushima Daiichi Nuclear Power Plant accompanied the Great East Japan 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, to gain a better understanding of the impacts of radioactive contamination on wildlife and ecosystem health, we implemented a study of the dynamics of radioactive materials in multimedia environments by using field measurements and multimedia fate modeling. We summarize the main results below.

(1) Analysis of stocks and flows of ^{137}Cs in the Kasumigaura Basin

To gain an understanding of the dynamics of ^{137}Cs deposited to date on a basin scale since the accident at Fukushima No. 1 nuclear power plant, we performed field surveys to quantify the flows and stocks of ^{137}Cs in the basin of Lake Kasumigaura. First, to examine the stocks in the basin, the average accumulation of ^{137}Cs deposited over the basin's entire land area was estimated to be 14 kBq

m^{-2} by geostatistical analysis using data from an airborne monitoring survey conducted on 11 November 2011 by the Ministry of Education, Culture, Sports, Science, and Technology. Also, the average accumulation in the lake sediments was estimated to be 17 kBq m^{-2} from interpolated data with a spatial resolution of 250 m; these data were taken from measurements of the activity of ^{137}Cs in sediment cores taken in December 2012 to a depth of 15 cm at 80 points covering the whole lake (Fig. 10). From the measured flux of suspended solids (SS) and the weight concentration of ^{137}Cs in SS sampled at a point downstream of each of the seven main rivers flowing into the lake, we estimated that the total ^{137}Cs runoff volume per unit area during the year after the accident ranged from 0.026 to 0.18 kBq m^{-2} and corresponded to 0.15 % to 0.52% to the total deposition into each of the main river catchments. By assuming that the percentage runoff of ^{137}Cs was 0.5%, we estimated that the total runoff volume of ^{137}Cs from the entire land area of the basin was 1.7×10^8 kBq in the 21 months after the accident, corresponding to only 5.9% of the whole accumulation of ^{137}Cs in the lake sediment. This small percentage indicates the small contribution of ^{137}Cs accompanying influent SS to radioactive contamination of the lake sediment. The substantial accumulation of radioactive Cs in the lake sediments is therefore likely to have been caused by direct deposition on the lake surface at the time of the accident and by the runoff of radioactive Cs from impervious areas, such as urban districts in the basin, soon after deposition.

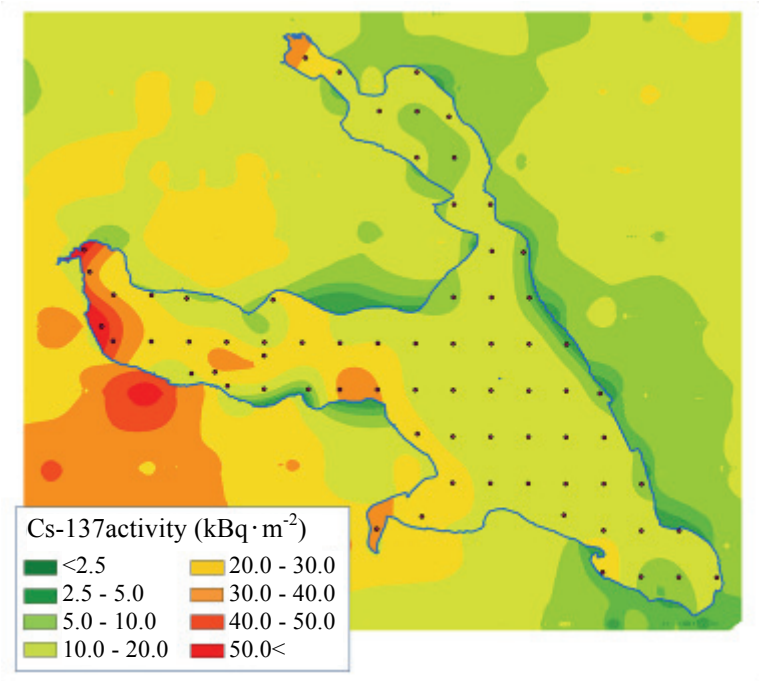


Fig. 10 Spatial distribution of accumulation of ^{137}Cs (resolution, 250 m) in the sediments of Lake Kasumigaura. For the estimates we applied the spatial interpolation method with a spline function to the measured activities of ^{137}Cs in sediment cores taken in December 2012 to a depth of 15 cm at 80 points (brown dots) covering the entire lake.

(2) Multimedia fate modeling

We have been developing a multimedia fate model for 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 the 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 the 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 at grid-based and appropriate geographic resolutions. This year we studied the fate modeling of radioactive Cs surrounding the Fukushima Region. In the atmospheric modeling, we assessed the model performance in simulating the deposition patterns of ^{137}Cs by making use of airborne monitoring survey data. We conducted 10 sensitivity simulations to evaluate the atmospheric model uncertainties associated with key model settings, including emission data and wet deposition modules. In the terrestrial multimedia modeling, we continued our long-term simulation of terrestrial fate processes in the region. This year we studied the incorporation of new runoff modules and the development of relevant datasets. In the ocean modeling, we conducted numerical simulations of oceanic dispersion and sedimentation of ^{137}Cs by using a high-resolution 3D model. On the basis of the simulated results, we developed a bioconcentration model and evaluated the ^{137}Cs concentrations in bivalve mussels on the coast of Fukushima Prefecture. Figure 11 shows the results of our current simulation of the fate of ^{137}Cs, using the atmospheric transport and deposition model, terrestrial model, and ocean model.

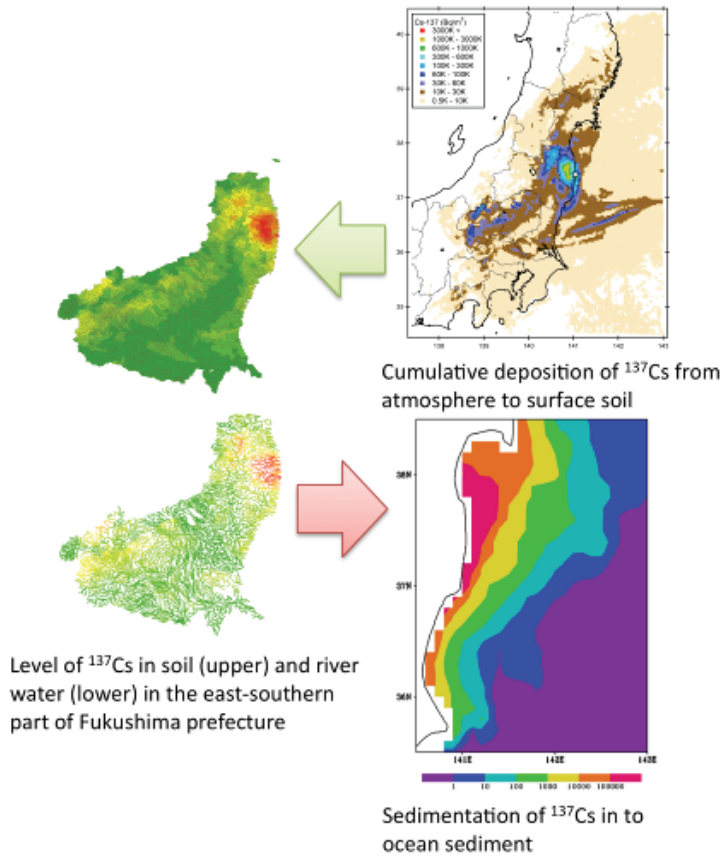


Fig. 11 Trial simulation of the fate of ^{137}Cs in and around Fukushima Prefecture, using combined atmospheric transport and deposition, terrestrial fate, and coastal sea models.

(3) Exposure modeling

To better understand and to estimate the long-term radiation dose from the Fukushima incident, we have formulated an exposure model. The model was built by using a set of data that we collected, as well as ones provided by other institutions. We collected house dust samples from an area where we had observed relatively high radiation levels (i.e. a "hotspot"). We measured radiation in the bulk house dusts and in the samples after 250-μm sieving, and we then calculated an enrichment factor to estimate the ingestible portion of radiation. Comparison of the model outputs with personal monitoring data also collected in the hotspot area revealed reasonable agreement. In most cases the total exposure did not exceed 1 mSv a year. External exposure of all age groups accounted for ~90% of total exposure, whereas diet accounted for ~10% (Fig. 12). Exposure from other sources was estimated to be minor.

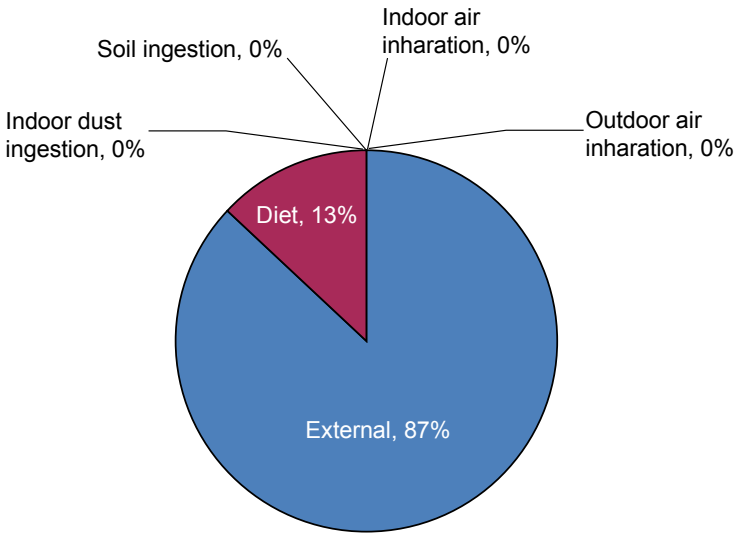


Fig. 12
Estimated routes of exposure to radiation from ^{134}Cs and ^{137}Cs in children aged 1 to 6 in the city of Kashiwa, in Chiba Prefecture.

(4) Effects of low-level gamma-irradiation on wild animals and transgenic plants

To clarify the impact of gamma-radiation from contaminated soil on wild organisms in Fukushima Prefecture, we (1) examined the effects of gamma-irradiation on the reproductive organs of wild rodents, and (2) developed transgenic plants that can detect DNA damage caused by radiation.

(1) Wild Japanese field mice (*Apodemus speciosus*) were captured in a high-gamma-dose area in Fukushima Prefecture and in low-gamma-dose areas (Aomori and Toyama prefectures). These animals were used for anatomical observation and for immunostaining analysis by using 8-OHdG antibody. The results showed that genomic DNA of sperm was markedly oxidized in *A. speciosus* from Fukushima; this DNA oxidization was not observed in the spermic DNA of the wild mice from other places (Fig. 13a).

(2) To detect homologous DNA recombination resulting from DNA damage by gamma-irradiation, we established four independent transgenic plants in which we introduced a GU-US construct (a gene encoding beta-glucuronidase was separated into two parts with 600 bp overlapping). These plants were grown on contaminated soil collected from Fukushima. Thereafter, GUS staining analysis was performed to estimate the frequency of DNA recombination (Fig. 13b). Among these transgenic plants, one line, designated #1406, showed linearity between DNA recombination and dose of irradiation. This suggests that DNA damage incurred through gamma-irradiation can be assessed quantitatively by using transgenic plants.

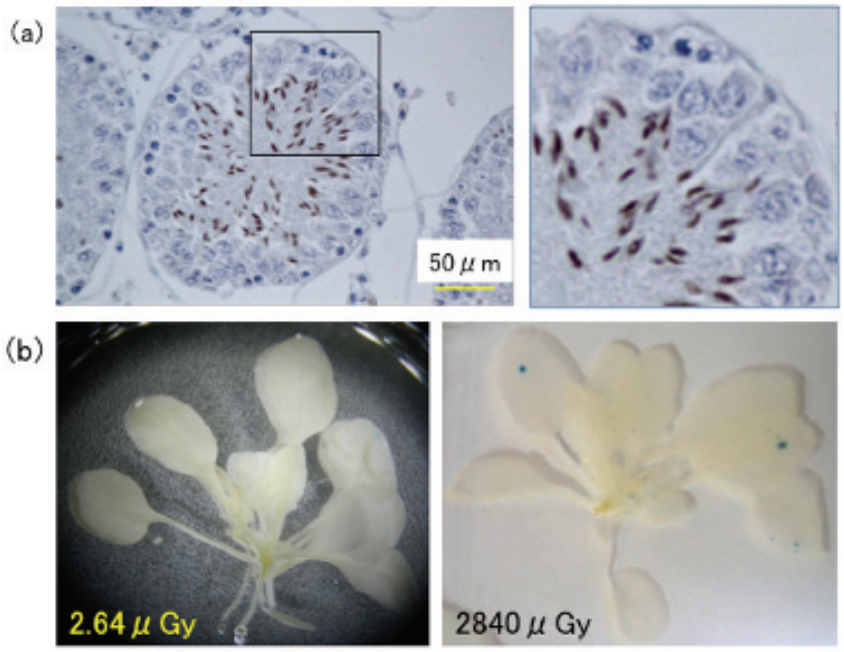


Figure 13
(a) 8-OHdG immunostaining of sperm cells of wild Japanese field mice. Left, a seminiferous tubule stained with 8-OHdG antibody. Right, higher magnification of the square region in the panel at left. Cells with oxidized DNA are stained brown.
(b) Appearance of GUS spots in plants grown at different radiation levels. Integrated values of radiation are shown at the bottom left of each panel. GUS-derived spots are blue-green.

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